Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

A McGraw-Hill Publication

Two Dollars

SEPTEMBER 1959

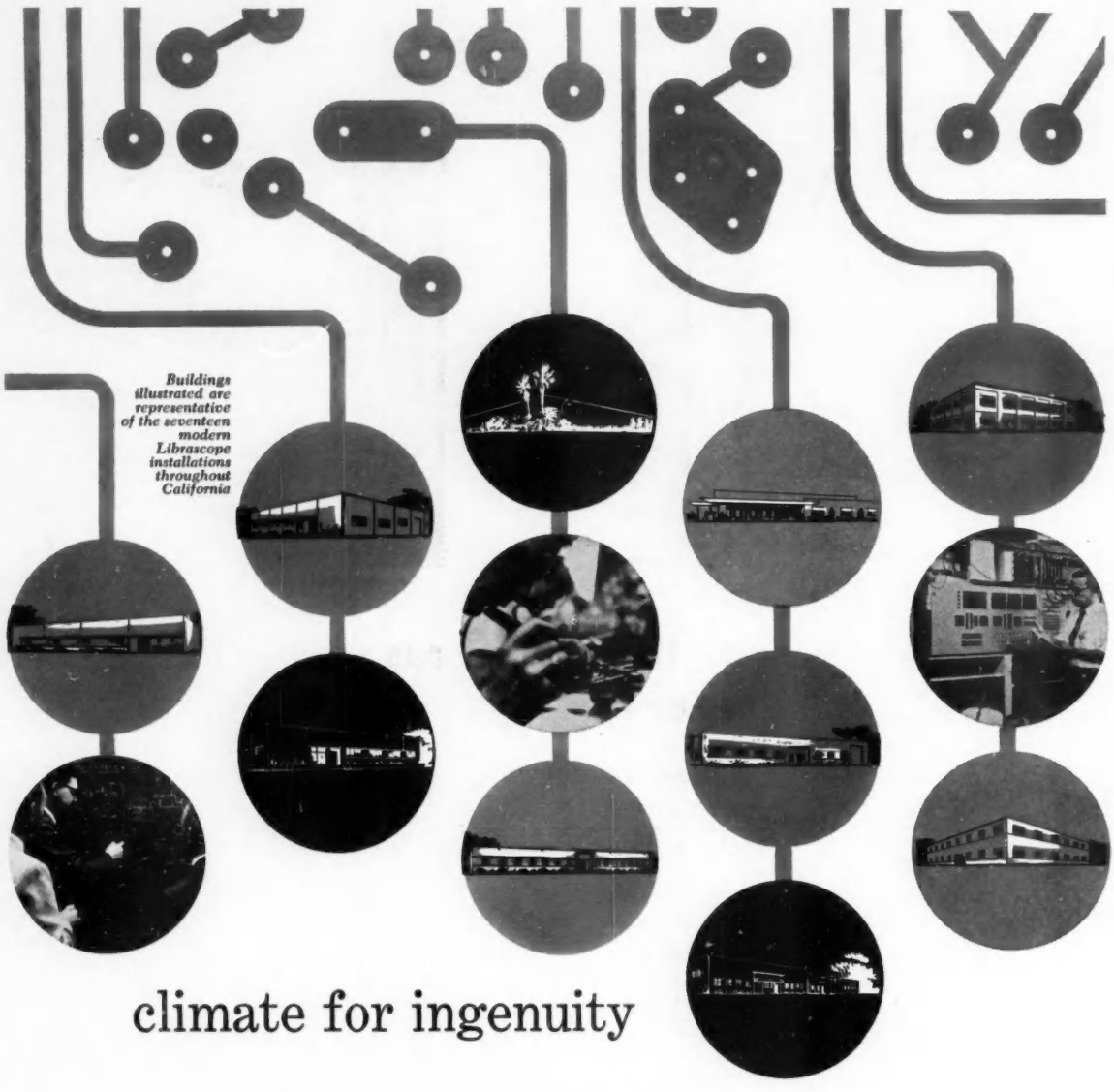
TESTING for Research, Design and Improvement

Planning Efficient Tests

What to Test

Basic Testing Functions

Plus 12 Case Studies of Test



Buildings illustrated are representative of the seventeen modern Librascope installations throughout California

climate for ingenuity

'Facilities' is more than a masonry-and-steel term at Librascope...it represents an overall regard for the tools of creative engineering—climate, time, equipment.

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For more than 20 years, Librascope has been recognized as a leader in the development of controls, computers and components...answering military and commercial requirements with timeliness and ingenuity.

Today, Librascope's *'facilities'* continue to grow at a rapid pace...providing an ever-expanding climate for ingenuity.

LI 9-19

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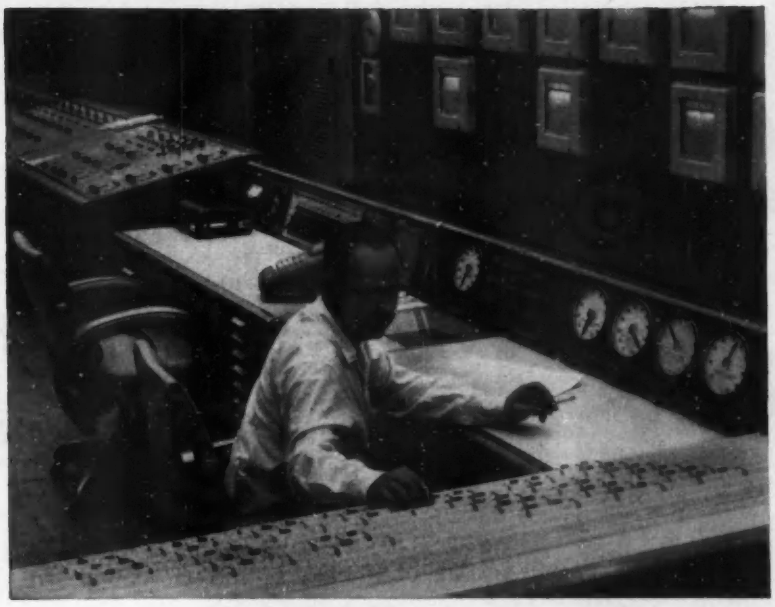


In operation since March, this L&N computer gives Florida Power & Light Co. the desired generation loading pattern on its nine major plants for strict incremental loading, or modified economy loading. The computer can also be used to study anticipated operating problems and their effects on the cost of operating the system while the load control is still in operation.

L&N computers close the control loops on 6 major power systems

FLEXIBLE NEW COMPUTERS KEEP SYSTEM OPERATION AT OPTIMUM LEVEL OVER WIDE RANGE OF CONDITIONS

"It's gratifying to know we made the right decision." So said H. W. Page, Manager of Power Supply, Florida Power & Light Co., as he reviewed initial months of operation with his new control. He went on to say, "We know now that as a result of our decision to install this computer, we have advanced the overall level of operating efficiency on our system even more than we expected. The equipment does its job in a thoroughly dependable manner."

Suggestion: you can help *your* system make the move to advanced automatic economy dispatching more objectively—and with confidence—by checking *results* first . . . the actual operating results being obtained right now from California to Carolina, from Connecticut to Florida (names on request). Then contact our local office, or 4918 Stenton Ave., Phila. 44, Pa.

GET RESULTS ON YOUR SYSTEM WITH AN L&N COMPUTER THAT:

1. *Automatically loads generating units on an incremental cost-of-power-delivered basis—includes incremental generating costs and transmission loss factors (transmission loss matrix optional).*

2. *Provides real operating flexibility: loads on any desired incremental, or modified economy basis, to meet prevailing system conditions.*

3. *Plots "on-the-spot" graphic answers to problems involving economy interchange, power-flow losses or anticipated loading patterns.*

4. *Derives a measured lambda value —incremental cost of power delivered—at all times.*

5. *Invariably adjusts generation in a direction that reduces area requirement.*

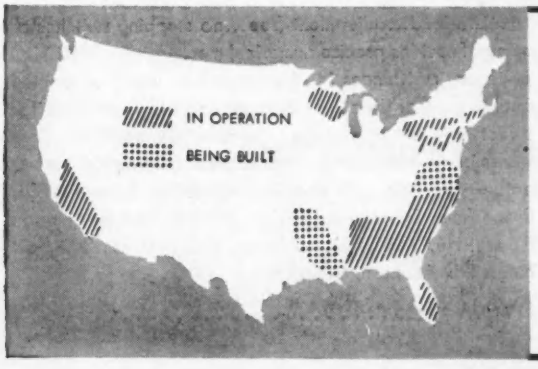
6. *Gives each unit a terminal destination.*

7. *Makes it easy to place units on control—just flip a switch—no synchronization required.*

8. *Provides safety margins: adjustable load limit settings are positive, and cannot be exceeded; maximum rates of control action are positive, adjustable, and cannot be overridden.*

9. *Costs less in the long run: requires no unit or governor modifications, goes into service after approximately two to four weeks installation procedure, gives positive assurance against overregulation.*

10. *Is easy to operate—gives any desired readout data and, in the opinion of maintenance men, needs relatively little care.*



Already, L&N computers direct the control of approximately 11,000,000 Kw over a large part of the country on systems representing a wide range of operating problems. Shaded area shows territory served by an additional 5,000,000 Kw to be put under L&N computer-control during the remainder of this year.

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DVOM price $1,475

Ask for a demonstration.

Epsco

First in data control

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Control ENGINEERING

SEPTEMBER 1959
VOL. 6 NO. 9

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

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WHAT TO TEST

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Accuracy	determined by basic counting instrument.
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* 4 lines per second printout * Takes 1-2-2-4 or 1-2-4-8 four line code * No stepping switches * Operates from only 6 volt input * Parallel entry * Special options available including 10 line and analog output * 6 digit printout, up to 12 digits on special order * Rugged unitized construction * Completely compatible with CMC's new solid state frequency-period counters, and other types of transistorized counting equipment.

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CIRCLE 6 ON READER-SERVICE CARD

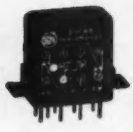
. . . they're both my babies

. . . but what a difference

Despite their identical appearance, those young innocents are barely fraternal. They *are* destined for fame, but along different Roads of Life.

The one on the left latches magnetically, eats only 50 mw. and works best in a circuit designed expressly with his characteristics in mind. He's also a few months older than his colleague, and has already made solid friends with at least one big military group. They like his particular combination of magnetic latching operation, high sensitivity, and ability to take 30 g's of vibration to 5000 cycles and 100 g shocks both on paper *and* in the flesh.

The little fellow on the right, on the other hand, offers a ready *replacement* suitable for existing equipment where standard DPDT switching is needed and the signal level is up around 200 mw. As such he's looking forward to making an even wider circle of friends than his companion — especially since he can take just as much vibration and shock and is put together with exactly the same care and high class materials.



Both of these hermetically sealed prodigies are described in their birth certificates which you can get for the asking. If you think the 50 mw., magnetic latching, left-hand one is for you, ask for the *Series* 32 specs; if it's the right-hand, "on-off" one you're interested in, specify *Series* 33. Don't try to go by looks — everything's coming in crystal cans these days.

* Sigma Corporate Image

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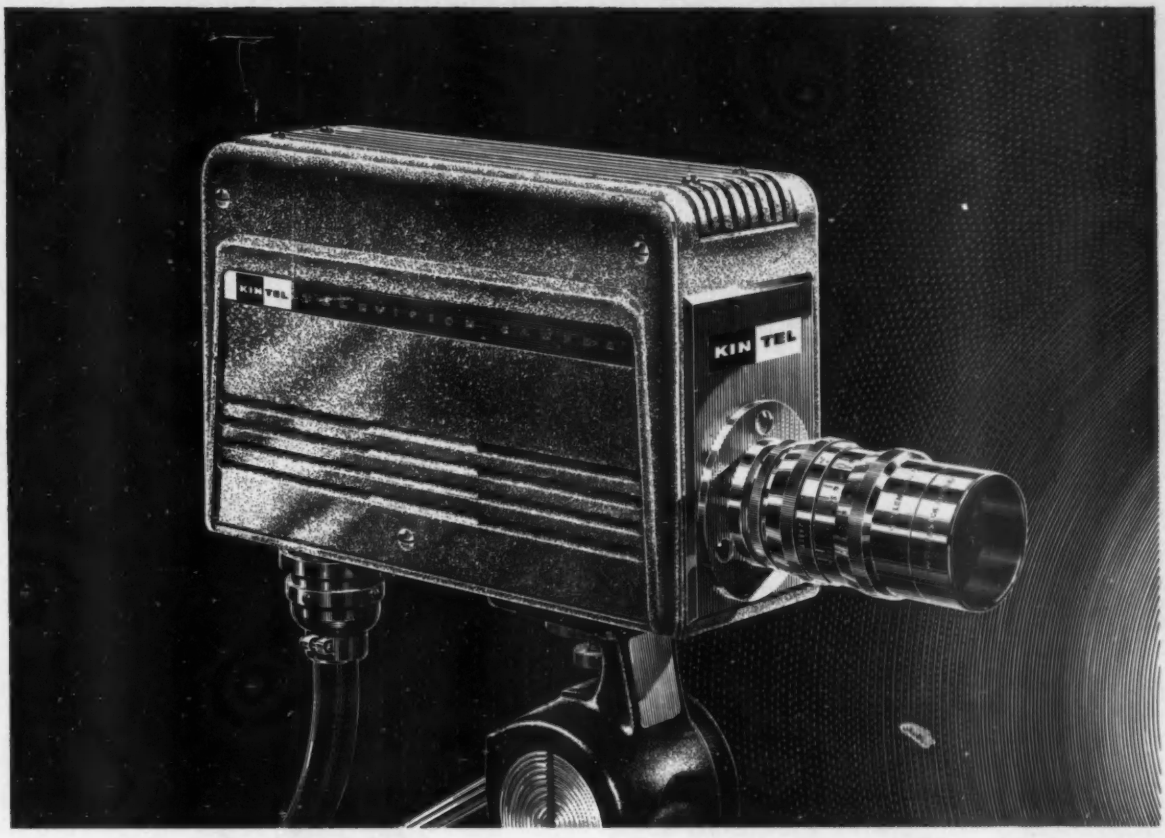

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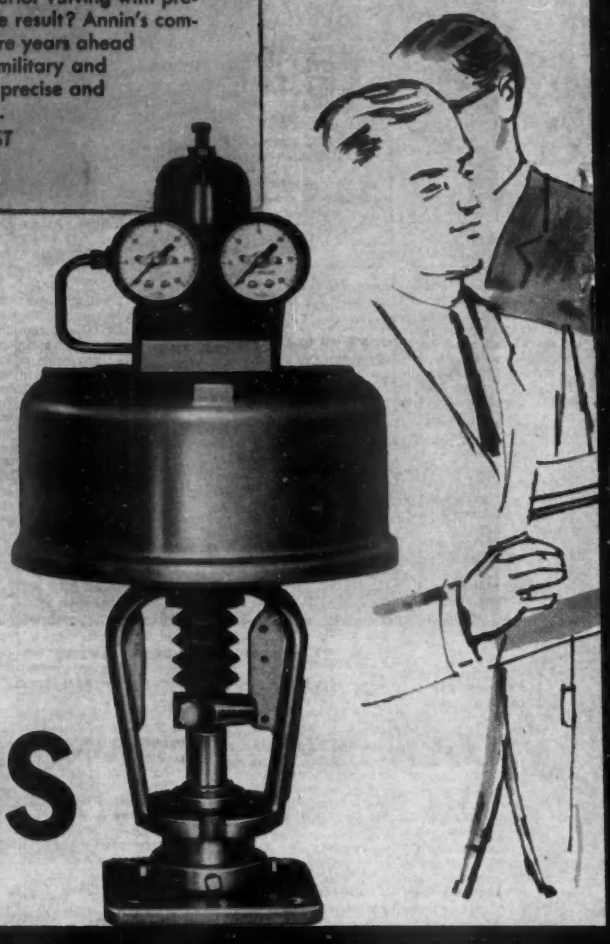

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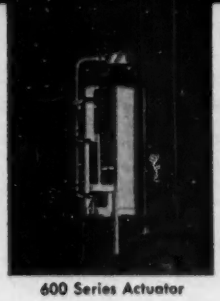

600 Series Actuator

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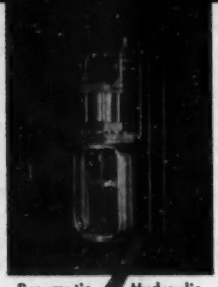
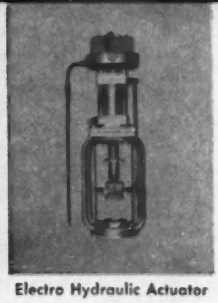
Toggle Actuator



Pneumatic Hydraulic Actuator



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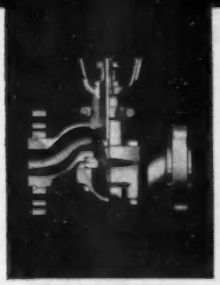
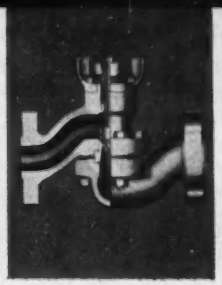
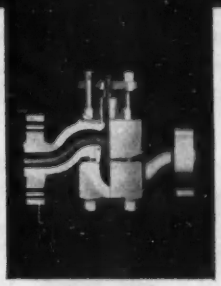
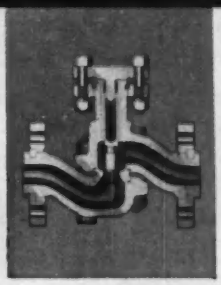
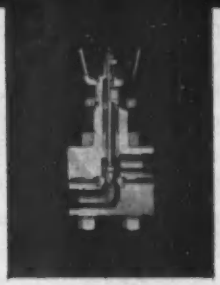

15 Group Body
600 lb. ASA rating


45 Group Body
1500 lb. ASA rating


65 Group Body
2500 lb. ASA rating


Check Valve Body
600 to 2500 lb. ASA ratings


34 Group Body
2500 and 10000 lb. ratings

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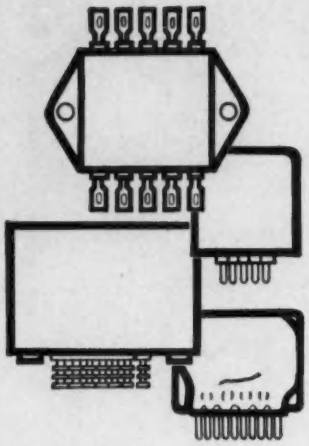

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SHOPTALK

CtE's wooden anniversary

With this issue, CONTROL ENGINEERING starts its sixth year of publication. The last five years have seen a continually growing recognition of the importance of the control engineering function by control users and makers, by the technical societies, and by educational institutions. But this is only the beginning. The next few years will undoubtedly see the control engineer playing an increasingly significant role. If the period since September 1954 has gone as fast for you as it has for us, you'll want to read Industry's Pulse (page 113) to see just how much has been crammed into these fleeting years.

Features back-to-back

We've abandoned our practice of placing advertisements between features for this issue, feeling that the reader would probably keep the articles together because of the integrated nature of the coverage. But reader response has been overwhelmingly in favor of this ad insertion, so from now on you'll be able to tear out any feature without also getting a page of the adjoining article.

Overtime for the editors

On top of the normal magazine workload, four members of CtE's staff have been preparing papers and organizing sessions for the annual ISA meeting, to be held in Chicago the week of September 21st. Editor Bill Vannah will talk on "Communication Links in the User-Contractor-Vendor Triangle" as a neutral observer on the Chemical and Petroleum Panel on Communication, Managing Editor By Ledgerwood will lead off the Instrumentation and Management session with "Control Systems Engineering and Its Meaning to Management", Associate Editor Harry Karp is organizing and chairing the Data Handling Workshop, while Associate Edifor Lew Young is chairing the session covering Economic Justification of Instrumentation.

New keeper of the copy

We've recently had one of our infrequent personnel changes. Our new copy editor, Stephen S. Livers, who replaces Warren Kayes, is an ME graduate from the University of Pennsylvania and more recently engineering proposals editor at Hamilton Standard. He'll birddog the copy and keep the rest of us editors on the grammatical straight and narrow.

For AIR, OIL and WATER operation to 250 p. s. i.
SIZES ¼" · ⅜" · ½" · ¾"
TEMPERATURES to 250°F

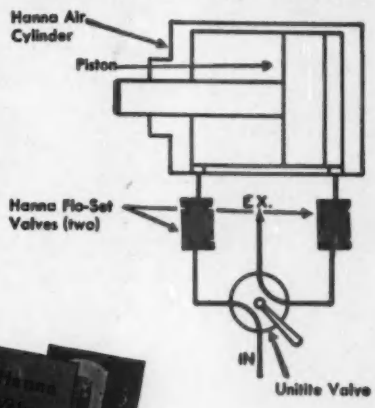
Hanna Flo-Set Valves are used to control cylinder piston speeds and operating speeds of many types of fluid actuated mechanisms. They are able to handle air, oil, water and many gases. When used with cylinders, these valves permit independent adjustments of forward and return piston speeds. The diagram at the right shows a typical circuit. Flo-Set Valves make the operation of air cylinders smoother and make cushioned cylinders more effective by building up essential back pressure.

Fluids pass unobstructed in the direction of the arrow on Hanna Flo-Set Valves. In the opposite direction, flow can be controlled from zero to full pipe capacity. One valve can be set to an infinite number of controlled flow positions. Once set, the position can be held by means of a locking collar. Established flow positions can be reset by using the micrometer graduations which accurately measure flow as a percent of full pipe capacity.

One revolution of the aluminum valve body will change the flow rate from zero to full capacity. No tools are necessary! In addition to the standard ¼", ⅜", ½" and ¾" sizes, there is a ¼" Jr. model, without micrometer graduations or locking collar, for light piping and tubing.

Typical Cylinder Circuit Using Hanna Flo-Set Speed Control Valves

Hanna engineers will gladly recommend circuits to help you with your applications.



Consult your classified telephone directory or Thomas' Register for your nearest Hanna representative. Write for Hanna Valve Catalog 254 and Flo-Set Valve Bulletin 253A.

Hanna Engineering Works

HYDRAULIC AND PNEUMATIC EQUIPMENT . . . CYLINDERS . . . VALVES . . . RIVETERS

1749 Elston Avenue Chicago 22, Illinois

CIRCLE 11 ON READER-SERVICE CARD

The shrill sound of a horn
echoes in every shaft
to guard this mine's air supply against...

CUTOFF!

This is a Pennsylvania coal mine.

Deep down in the earth, hundreds of men are working at the raw sides of jagged black tunnels.

At the surface, three giant fans—each remotely situated in the surrounding countryside—send fresh air sprawling through the many miles of entryway.

The link between man and fan is 4½ miles of Rome control cable!

Engineers at this mine* selected Rome control cable for the nerves of a meticulously engineered control system that guards the mine's vital air supply. A winking light in the control room means everything is running smoothly. *But . . .*

A shrieking horn means trouble! Before gases can accumulate in the mine—jeopardizing the lives of hundreds—repair crews get the signal and start working on the failing fan.

Cable for a control system such as this must be the ultimate in reliability. "We've had experience with Rome's borehole cable and other types of Rome cable," says the chief outside electrician, "so I recommended Rome's control cable for this important job."

It went up very quickly—a crew of seven strung the first 16,000 feet over rugged, wooded and hilly terrain in only 14 days. That's *half* the time such an installation normally takes. The reason? Rome supplied a factory-assembled self-supporting-type cable to save the time and expense of on-the-job assembly.

You depend on cable, too. Just as this coal mine relies on cable to breathe, your plant relies on cable for production—to drive machines and other plant equipment. Like the mine, you can't afford to take chances on power failures.

Rome Cable manufactures various types of thermosetting and thermoplastic control cables to meet specific electrical, environmental, installation and economic requirements. Call your nearest Rome Cable salesman today for help in selecting the precise cable you need.

*Name of mine furnished on request.

MEET THE MAN

WHO'S DEDICATED TO YOUR JOB

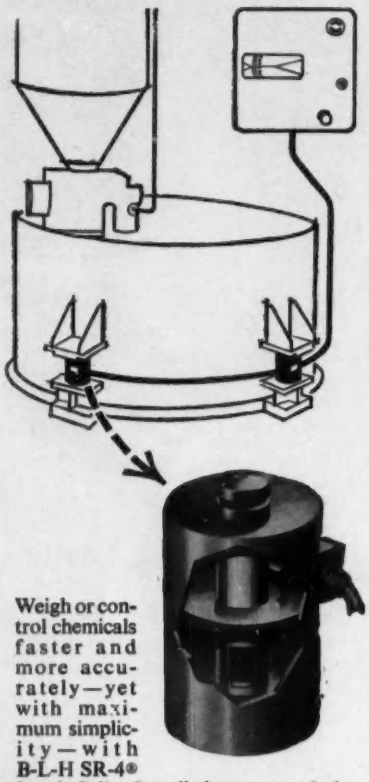
YOUR ROME CABLE SALESMAN

ROME CABLE

CORPORATION

MEASURING QUANTITY?

Then do it the modern way ... with accurate, rugged, trouble-free SR-4® Load Cells



Weigh or control chemicals faster and more accurately—yet with maximum simplicity—with B-L-H SR-4® Load Cells. Installed as part of the tank support structure, no part of the measuring system comes in contact with the contents of the tank. Can be installed on tanks already in use. Output suitable for use with local or remote indicator, recorder or automatic dispensing control. Explosion-proof. Hermetically sealed—unaffected by dust, grease or moisture; long service life assured. Available in standard capacities of 50 through 200,000 lb., accuracies to ±0.10%.

For more information on load cells and complete batching systems, write Dept. 6-I and ask for Bulletins 4355 and 4510

FIRST in force measurement

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CIRCLE 13 ON READER-SERVICE CARD

FEEDBACK

READERS' CONTROL WORKSHOP

TO THE EDITOR—

For some time we have been using a nomographic chart for determining the application characteristics required of different types of thermistors. This has been developed by our M. Kovarik and for normal applications uses only two scales. For this reason we believe it to be the simplest possible graphical solution. We are aware of the chart published in CONTROL ENGINEERING in February 1959 (Data File 23) which requires two nomograms.

A copy of the chart and description of its use is enclosed, because we thought that your readers might be interested in this simplification.

R. N. Morse
Commonwealth Scientific & Industrial Research Organization
Highett, Victoria, Australia

The relation between temperature and resistance of a thermistor $R = ae^{b/T}$ can be represented by a nomogram consisting of two scales only, if R (resistance) and T (temperature) are the only values of interest.

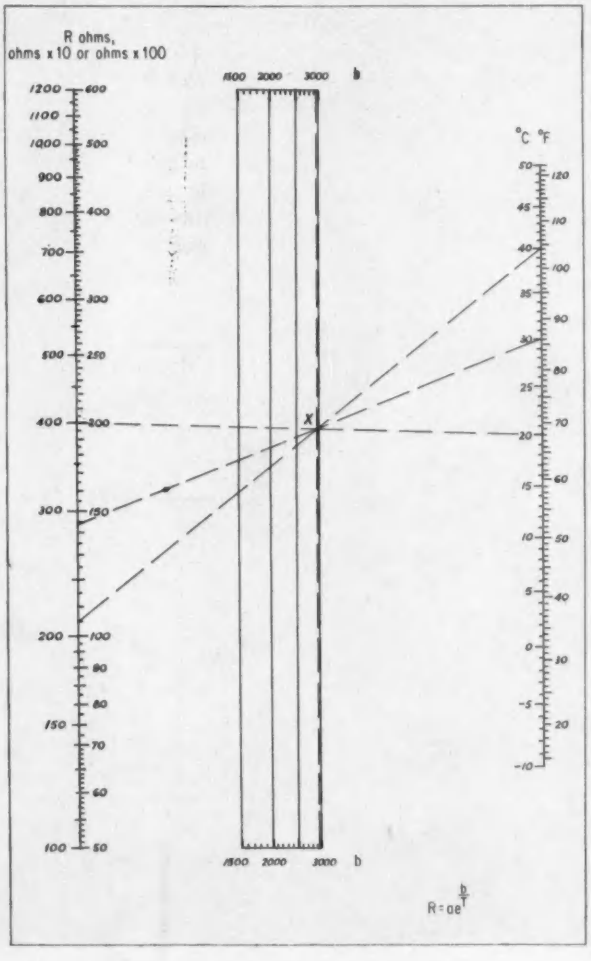
If the value of the constant b is required, it can be read off a series of parallel lines between the scales; these need not be considered where b is irrelevant. While the temperature scale cannot be varied, the resistance scale holds for any multiple of the resistance values represented.

Given two values of resistance R_1, R_2 at known temperatures T_1, T_2, the nomogram determines the resistance R_3 at any other temperature T_3.

An example covering the climatic range of temperature is shown. To use

Nomographic Chart For Thermistors

M. KOVARIK



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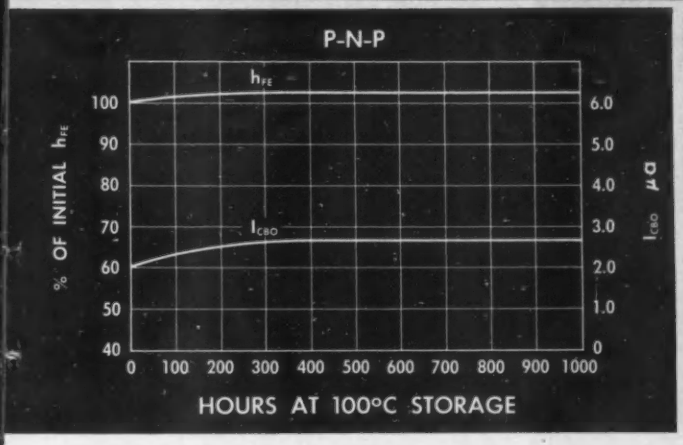
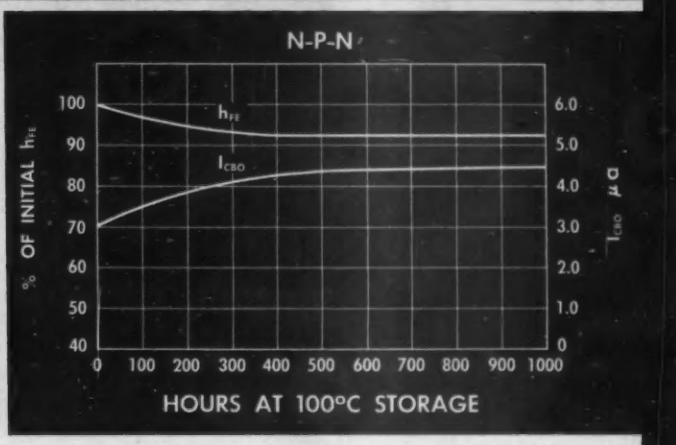
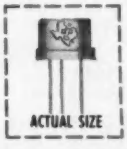
10,000,000 LIFE TEST HOURS





TI COMPLEMENTARY COMPUTER TRANSISTORS!



Now commercially available... and backed by more than 10,000,000 hours of recorded life test reliability data... eight types of performance-proved P-N-P and N-P-N alloy-junction germanium computer transistors! Take advantage of the high-reliability/low-cost benefits made possible by manufacturing economies already realized in 1½ years of high-volume production to the stringent requirements of International Business Machines Corporation. Mechanized production equipment *has been built*... quality assurance controls and techniques *have been perfected*... and are in full use *now*, making these high-volume/high-reliability/low-cost units a reality *today*. Check the detailed specifications below and call your TI distributor or sales engineer for the low prices of these new computer transistors.

COMPLEMENTARY TI COMPUTER TRANSISTORS		MAXIMUM RATINGS AT 25°C							ELECTRICAL CHARACTERISTICS AT 25°C									
		Emitter-Base Voltage	Collector-Base Voltage	Collector-Emitter Voltage	I_C Collector Current	I_E Emitter Current	T_{stg} Storage Temperature	P_o Total Device Dissipation*	I_{CBO} † Emitter Reverse Current		I_{CBO} † Collector Reverse Current		h_{FE} † Current Transfer Ratio		h_{FE} † Current Transfer Ratio		$f_{\alpha_{ob}}$ † Alpha Cutoff Frequency		C_{ob} † Output Capacitance	
									V_E=25v, I_C=0		V_C=25v, I_E=0		I_C=10ma, V_{CE}=1v		I_C=200ma, V_{CE}=0.35v		V_{CB}=5v, I_E=−1ma		V_{cb}=5v, f=1mc	
									Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
2N1302	N-P-N	25	25	25	300	−300	↑	↑		6		6	20		10		3			20
2N1303	P-N-P	−25	−30	−25	−300	300				−6		−6	20		10		3			20
2N1304	N-P-N	25	25	20	300	−300				6		6	40	200	15		5			20
2N1305	P-N-P	−25	−30	−20	−300	300	−65 to 100	150		−6		−6	40	200	15		5			20
2N1306	N-P-N	25	25	15	300	−300				6		6	60	300	20		10			20
2N1307	P-N-P	−25	−30	−15	−300	300				−6		−6	60	300	20		10			20
2N1308	N-P-N	25	25	15	300	−300				6		6	80		20		15			20
2N1309	P-N-P	−25	−30	−15	−300	300	↓	↓		−6		−6	80		20		15			20
	Units	v	v	v	ma	ma	°C	mw	μa		μa						mc		μμf	

* Derate at 2.5 mw/°C increase in ambient temperature over 25°C.

† Conditions listed apply to N-P-N. Negative values used for P-N-P.

germanium and silicon transistors
silicon diodes and rectifiers
tantalex solid tantalum capacitors
precision carbon film resistors
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INCORPORATED
SEMICONDUCTOR-COMPONENTS DIVISION
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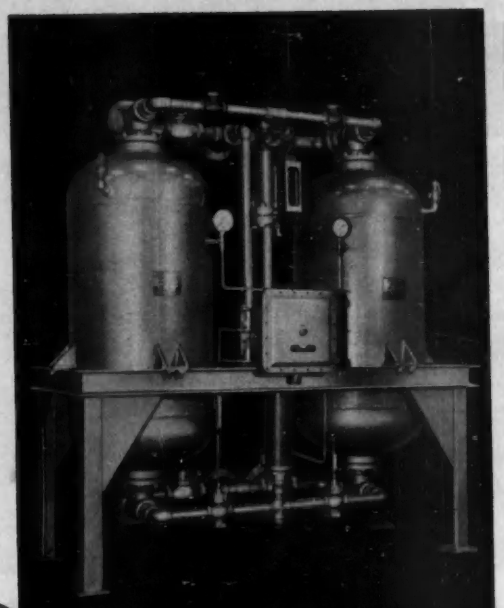
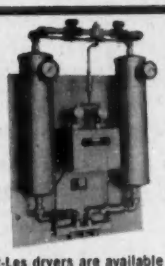
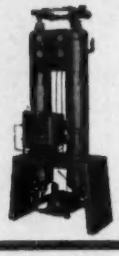
CIRCLE 14 ON READER-SERVICE CARD

some remarkable FACTS about the TRINITY Heat-Les DRYER





Heat-Les dryers are available in a wide range of capacities to meet all industrial and military needs.



1. **REJECTS OIL**—Eliminates the need for accessory oil filters and ensuing replacements of desiccant or filter cartridges.

2. **LOWER INITIAL COST**—Original equipment costs savings up to 50%, depending upon installation requirements.

3. **LOWER MAINTENANCE COSTS**—No heaters to service. Few moving parts. Designed for maximum life, minimum service requirements.

4. **COMPLETELY AUTOMATIC**—Requires no attention.

5. **DEWPOINTS AS LOW AS —180°F**—Standard guarantee—100° F at line pressure. Actual dewpoints below range of usual measurement.

Here's a working phenomenon so remarkably simple, yet so effective, you must see it to believe it. The Heat-Les Dryer is the practical answer to all industrial dynamic dehumidification needs.

WRITE FOR COMPLETE DETAILS...

Heat-Les Dryers are available in a wide range of sizes to meet practically all requirements, and are designed to operate at 30 to 6000 psig.

TRINITY

Heat and Heat-Les reactivated dryers.

Complete air supply and purging systems.

TRINITY EQUIPMENT CORPORATION, CORTLAND, NEW YORK

CIRCLE 15 ON READER-SERVICE CARD

the chart, follow these steps:

1. Connect resistance value R_1 to the corresponding temperature T_1 on the opposite scale by a straight line.
2. Connect resistance value R_2 to its corresponding temperature T_2 by a straight line.
3. Mark the intersection X of these two lines on the chart.
4. Any other corresponding pair of temperature-resistance values for the same thermistor lies on a straight line passing through the intersection X.
5. The value of b in the thermistor equation is measured by the position of X on the scale of parallel lines for b.

Numerical example:

Given
$R_1 = 2000$ ohms $t_1 = 20°C$ ($T_1 = 293.2K$),
$R_2 = 1050$ ohms $t_2 = 40°C$
$R_3 = 1435$ ohms.
then from nomogram
$t_3 = 30°C$ and $b = 2960$.

We pay for entries to Readers' Control Workshop or Problem Forum, if we publish them. Submit your problem or a solution neatly boiled down for use. Ed.

Wishes 'twere true, but 'tain't.

TO THE EDITOR—

We note that Mr. Burian's affiliation with G-M Labs, Inc. was omitted from the byline of the article on FM motors by him and our Mr. Jamieson in the May issue of CONTROL ENGINEERING, giving the impression that Mr. Burian is with Parametrics. Of course, we would be very happy if this were true, but, sad to say, it's not true. We have met with some confusion on the part of people wishing to obtain more detailed information from Mr. Burian, and would like to set the record straight.

R. E. Johnson
Parametrics
Cesta Mesa, Calif.

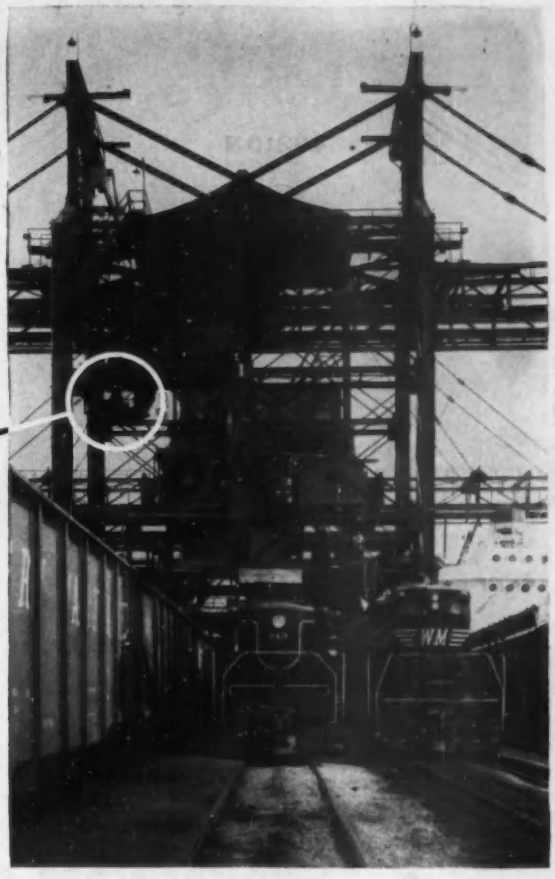
Brickbat meets a bouquet.

TO THE EDITOR—

This letter is written in response to Data File 27, "A Graphic Solution for the Damping of Cubic Systems", by Karl Eklund, which appeared in the June 1959 issue of CtE.

Specifically the points of issue here are the statements which appear at the top and bottom of the page inferring that the dynamic response of a linear

Automation from crane to customer's office at the Western Maryland



After unloading ore from ship to railroad car, weighman in crane transmits data to yard office for automatic preparation of waybill and other documents.

Teletype Printer in a crane automates ore waybilling

As ore is transferred from ships to railroad cars at Western Maryland's Port Covington docks, a weighman high up in the control cabin of the ore-unloading crane records the lot number, tonnage, and car data on a Teletype Printer. Instantly, this information is reproduced in the yard office in punched tape—starting the automatic writing of waybills by a combination of Teletype page and tape equipment.

The only manual intervention following the transmission of the variable data from the crane is the association of fixed-data tapes by the yard clerk. The entire procedure takes just minutes—so that when the last car is coupled to the train, all waybills, arrival notices, and consignees' copies are ready. Accuracy is improved, too—since mechanization eliminates recopying errors.

As a by-product of waybill preparation, a master tape is punched automatically, which is used to produce a complete shipping statement. The system also enables the Western Maryland to give customers an extra service to speed their own accounting procedures: advance direct wire transmission of shipping statement data by Teletype equipment or a duplicate of the master tape by mail.

This installation is just one example of how railroads today are using Teletype equipment in new, imaginative ways to trim costs, improve service. This unusual application is made practical by the ruggedness built into Teletype equipment, so that it functions dependably and economically even in the dust-generating environment of ore-loading operations. If you would like information on the new Teletype Model 28 Line, please write to: Teletype Corporation, Dept. 22J, 4100 Fullerton Avenue, Chicago 39, Illinois.

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SUBSIDIARY OF *Western Electric Company* INC.

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PROGRAMMED CONTROL

Concord Control is investigating programmed control problems associated with automatic electronic test equipment, automatic checkout and countdown equipment, and automatic simulation equipment for a number of aircraft and missile companies.

Many of these companies already have numerically controlled machine tool systems designed and manufactured by Concord. Others have heard of the advanced nature and extreme reliability of Concord systems.

If your programmed control problems require a high order of engineering design and equipment reliability, we can be of material assistance to you.

Contact Mr. H. P. Grossimon, our Engineering Vice President.

Concord Control Inc
1282 Soldiers Field Road, Boston, Mass

FEEDBACK

system is governed by only some of the poles of its transfer function. That is, the article states that if the denominator polynominal in s is a cubic, then for a stable system which may be factored into the product of a linear and quadratic term, the dynamic response of the system may be predicted by a knowledge of the well-known response of the quadratic factor. A moment's reflection on these statements will reveal their absurdity.

In conclusion, presentation of information such as contained in the referenced article is very worthwhile; however, in many instances, for the sake of economy of space, the material is not given a just exposition, and misinformation and confusion result.

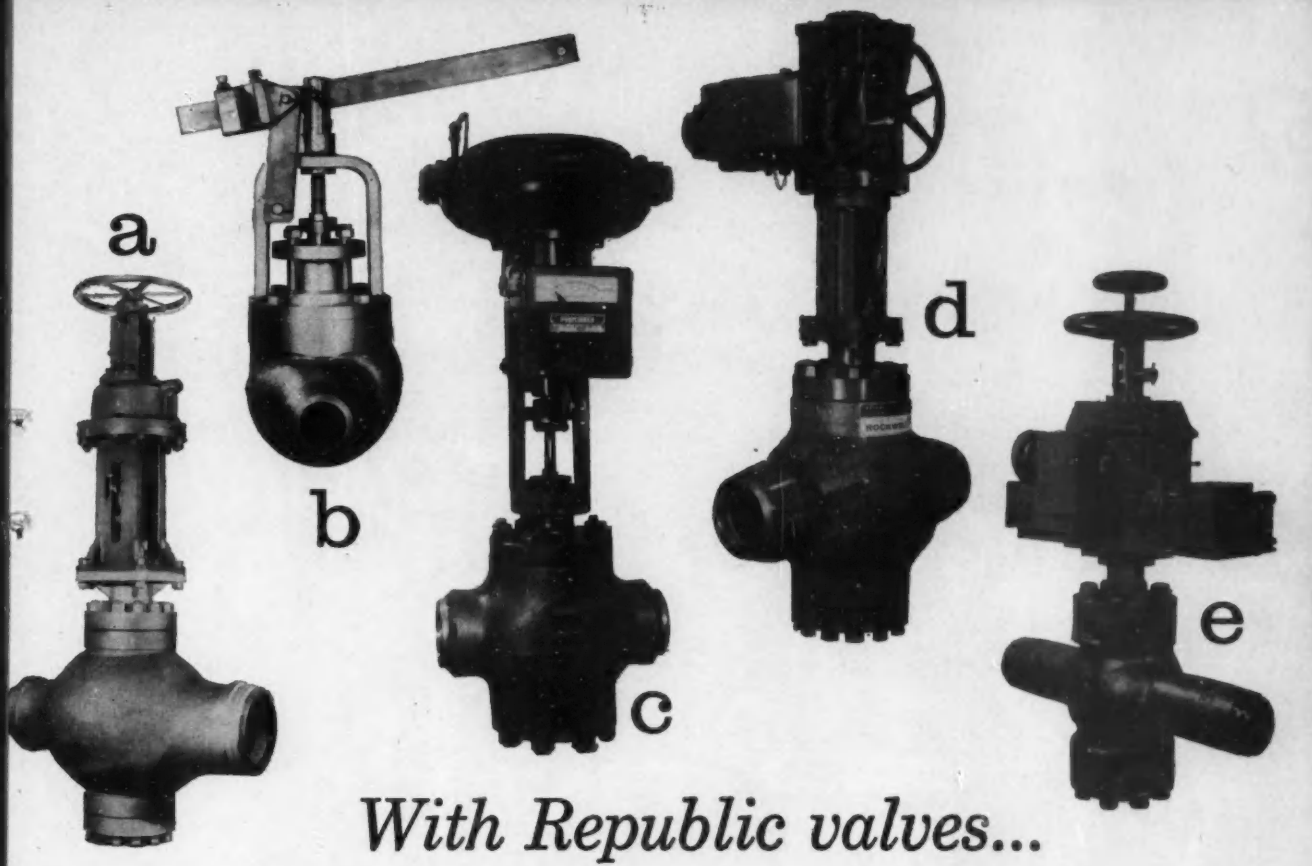
Morey M. Gibbs
Minneapolis-Honeywell Reg. Co.
Boston, Mass.

Mr. Morey Gibbs—

Some of what you say is correct. Both the real root and any s-dependent terms in the numerator have a profound and significant effect on the dynamic behavior of the system. I am sorry that you read into the article the implication that *only* the quadratic term was necessary to determine the dynamic behavior, but it was assumed, at least on my part, that those using the chart would realize that it was still necessary to do a partial fraction expansion to obtain the detailed time behavior described by the equation.

Concerning your last comment, I am of two minds. As an author of not much more than normal conceit, I would certainly agree that no effort should be spared to include every one of my golden words, and many of them were deleted in the publication of this manuscript. On the other hand, as a steady reader of several professional publications (from *Materials and Methods* through CONTROL ENGINEERING and to the august reaches of *The Physical Review* and others) I feel that the editors have done their usually fine job of presenting to a rather broad audience the overly loquacious work of a specialist. I feel sure, that as you have evidently done, the people to whom this data file is useful will easily recognize its limitations, and those for whom it has no interest will not have lost the material that might have been crowded out by several pages of not very significant details.

Karl Eklund
Parameters, Inc.
New Hyde Park, N. Y.



With Republic valves...

You get longer life, less maintenance

For over 35 years Republic valve developments have paced the changing demands for more sturdy valves by the most progressive utilities and industries. For such services as pump recirculation control, feedwater regulation, steam pressure reducing and high pressure water control, Republic valves have established a reputation for durability, long life and trouble-free performance.

Superior valve design—Republic research into the causes of valve noise and vibration, and also the wear resisting and galling properties of materials has resulted in a modern line of Republic valves of advanced design. Republic valve contours are designed to produce not only the desired regulating characteristics but also to reduce erosion damage and noise as well. Extra large guide bushings, extra deep stuffing boxes, solid plug inner valve construction, plus precise manufacture and long-life materials make Republic regulating valves perform better, last longer, with less maintenance.

Wide selection of valves and features—Rockwell-built Republic regulating valves shown on this page are representative of the complete Republic line:

a. **Cylinder operated valve**
b. **Lever operated valve**
c. **Diaphragm operated valve**
d. **Motor operated valve**
e. **Toggle head operated valve**
f. **Diaphragm operated angle valve**

And, for many special applications, such Republic accessories as pneumatic and electric valve positioners for hysteresis-free control, and a complete line of controllers are available.

Whatever your regulating valve problem, let Republic engineers put their years of application experience to work for you. For additional information, see your Republic representative, or write to Republic Flow Meters Company, 2240 Diversey Parkway, Chicago 47, Illinois.

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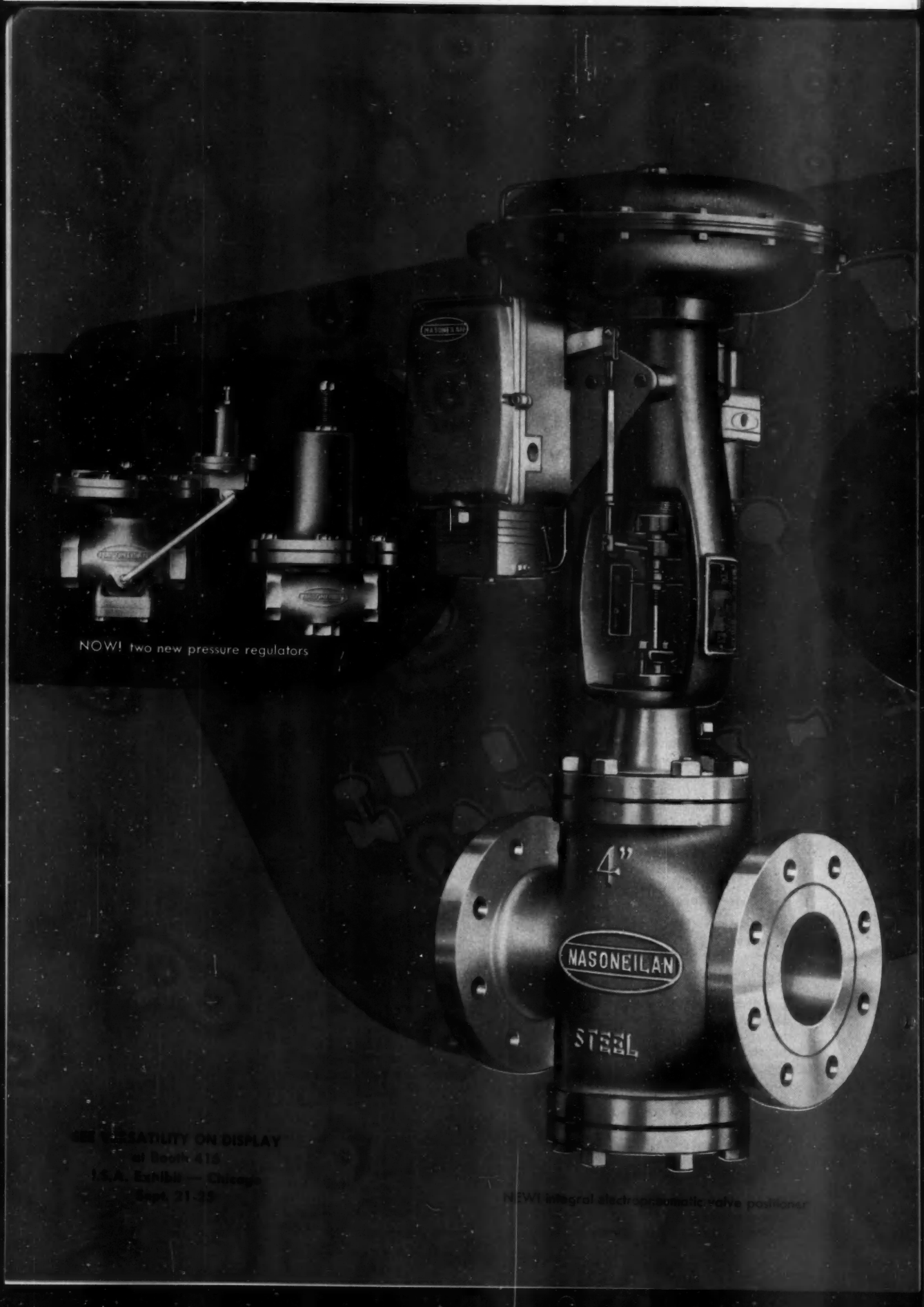
more fine products by
ROCKWELL

CIRCLE 17 ON READER-SERVICE CARD



NOW! two new pressure regulators

NEW! integral electropneumatic valve positioner

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With Mason-Neilan Controls...

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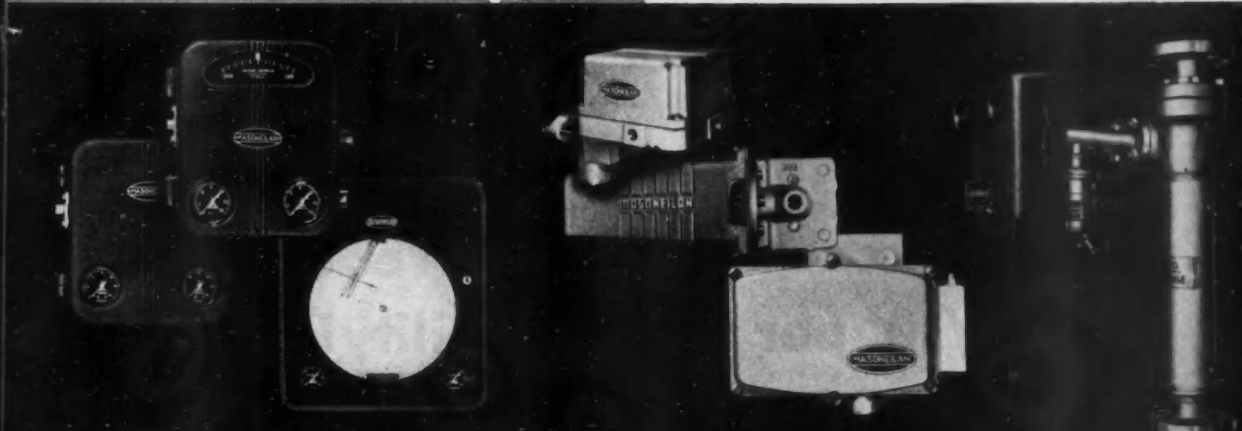

Control instruments, transmitters, transducers, liquid level controllers

The designed-in versatility of major Masoneilan product lines permits a selection of *standard* control equipment for all usual installations and many of the tougher applications.

- **Control Valves:** an exceptionally wide variety of body styles and trim types (many of them interchangeable) enables you to obtain the best combination for your particular service.
- **Indicating, Recording and/or Controlling Instruments:** built from unit subassemblies; permits the selection of desired components for the pneumatic control action or function desired.
- **Transmitters:** interchangeable primary elements simplify the transmission of pressure or temperature, flow or level measurement.
- **Positioners:** pneumatic or electropneumatic positioners and/or electropneumatic transducers offer a choice for either pneumatic or electric control systems.
- **Butterfly Valves:** the versatile butterfly valve line permits multiple variations by simple rearrangements of linkage; choice of actuator types, liners, seating or nonseating designs and mounting styles.

This "standard" versatility of Masoneilan products results in lower maintenance costs and reduced delivery delays. It will pay you to learn how this versatility can be adapted to *your* advantage. Call a Mason-Neilan representative or write for catalog.

NOW!
new developments in Masoneilan Butterfly Valves — soft seats, angle seating, body liners, actuators

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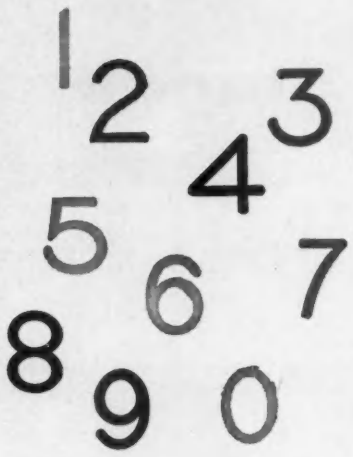
CIRCLE 18 ON READER-SERVICE CARD



Presenting hp 524D Electronic Counter

New 8-decade numerical readout!
New 5/10⁸ per week stability!

plus all these frequency and time measuring advantages!

Direct, instantaneous, automatic readings
Frequency coverage 10 cps to 220 MC*
Time interval 1 μsec to 100 days
Resolution 0.1 μsec
High sensitivity, high impedance
No calculation or interpolation

SPECIFICATIONS

(Basic 524D without plug-ins)

Frequency:
- **Range:** 10 cps to 10.1 MC
- **Gate Time:** 0.001, 0.01, 0.1, 1, 10 secs or manual
- **Accuracy:** ± 1 count ± 0.000005%
- **Reads in:** KC. Automatic decimal

Period:
- **Range:** 0 cps to 10 KC
- **Gate Time:** 1 or 10 cycles of unknown
- **Accuracy:** ± 0.3% (1 period) ± 0.03% (10 period average)
- **Stan. Freq. Counted:** 10 cps, 1 KC, 100 KC, or 10 MC, or external
- **Reads in:** Secs, msec, μsec

General:
- **Registration:** 8 places (99,999,999 max.)
- **Stability:** 5/100,000,000. May be standardized with WWV or external 100 KC or 1 MC primary standard.
- **Display Time:** Variable 0.1 to 10 secs; or "Hold"
- **Input Voltage:** 1 v min, 1.5 v peak. Rise time 0.2 seconds max.
- **Input Impedance:** Approx. 1 megohm; 40 μμf shunt.
- **Price:** $2,150.00 f.o.b. factory.

Data subject to change without notice

New convenience of uniform 8-decade numerical readout without meters — new 5 parts in 10^8 stability simplifying standards and other microwave measurements — this is the capsule story of the new *-hp-* 524D Electronic Counter.

Electrically similar to the widely used *-hp-* 524B Counter, the new 524D provides for full frequency measurements from 10 cps to 10 MC and period measurements from 0 cps to 10 KC. Low cost plug-in units extend frequency measuring range to 220 MC, permit period measurements of over 10,000 periods, and increase sensitivity for precise measurement of weak signals. Still another plug-in provides for time measurements from 1 μsec to 100 days with 0.1 μsec resolution. When used with *-hp-* 540A Transfer Oscillator, the 524D will measure accurately to 12 KMC. For complete details, write or call your *-hp-* representative; or write direct.

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FIELD REPRESENTATIVES IN ALL PRINCIPAL AREAS

*with plug-ins

hp world's most complete line of electronic counters

Earl Hatcher

converts data on the missile range

At the Atlantic Missile Range, the sole output and product is information. Converting the data from range instrumentation to a form that can be used by the computers which turn out this urgent information is the job of RCA Service Co.'s Data Translation Engineering, whose chief is a tall Kentuckian, Earl Hatcher.

Since he joined the Atlantic Missile Range as a civilian engineer in 1954, when it was known as the Air Force Missile Test Center, Hatcher has worked to boost the "real time" capabilities of the range. During his first days at the Cape, data from range instrumentation was collected in a variety of ways—films, magnetic tapes, and punched cards—and days, or even weeks, later they were converted to a form usable in FLAC, the Florida Automatic Computer. A minimum amount of information was brought out in analog form and plotted so the range safety officer had some idea of what the missile was doing.

Hatcher's group has worked to change all this. It designed and developed a device to automatically translate DOVAP signals (a tracking technique that uses a continuous sine wave signal broadcast to a missile and then rebroadcast back to the ground) directly into computer language. For the Vanguard satellite shoots, it planned the tie-in of two radars, over the then unheard-of distance of 165 miles, directly to large scale, general purpose, digital computers, which would compute predictions of impact during propulsion (where the missile would fall if fuel were cut off) and apogee (point of highest flight at which third stage ignition takes place).

Another of Hatcher's pet projects has been the development of techniques and equipment to record radar tracking data on magnetic tape so that it could be read directly into large scale computers. Before this development, radar trajectory data was recorded, and at a later date, converted to computer format. The new method cuts hours from data processing time. As an extension of this work, Hatcher has pioneered the direct readout of data from teletype lines into IBM 700 computers.

A three year hitch in the Navy during World War II introduced Earl Hatcher to the expanding world of electronics. As a Radioman First Class, he learned enough to want to make a career of it. When the war ended, he enrolled at the University of Louisville and earned his BEE degree in 1950. His first job after graduation was with IBM in Louisville, application work on punched card data processing equipment.

In 1954, a newspaper ad, which heralded the boom in missile work around Cape Canaveral and which ended with the admonition: "Come to Florida", caught Hatcher's eye. He succumbed to both inducements. Florida has lived up to its reputation as a good place to live and the missile work has really boomed.

At first, he was assigned to the data reduction group. Later, the group's responsibilities were expanded to include engineering for real time data recording, transmission, and computation. Hatcher became manager of this new activity.

In the frantic schedule which he follows, Hatcher frequently works on projects that are years off, months off, and days off—all at the same time. Sometimes it is hard for the instrument engineer to keep track of everything that's happening. Just recently, when a visitor asked Earl what he thought of a shoot which had taken place the day before, Earl's first comment was "You mean that's gone off already?"

The bulk of Earl's outside activities are tied to missile work too. He is a member of both the telemetry working group and the data reduction and computer working group of the Department of Defense's Interrange Instrumentation Group (IRIG). He has found time to become active in the Eau Gallie (one of the "bedroom" towns that have sprung up around Cape Canaveral) Junior Chamber of Commerce, was its president in 1957-58, an experience which has been helpful at the Cape when he has to turn salesman to sell a new instrumentation technique.

Right now, Hatcher worries because he feels "there is still a gap between the ground-base data processing computer and the missile guidance system." Hatcher has helped to narrow the gap by pushing the use of the impact predictor with a big computer, the IBM 709 (CtE, Jan. 1959, p. 23). He thinks the gap will be narrowed even more when the new AZUSA Mark II becomes the input to the impact predictor system later this year. He predicts, "We'll cut our error from one mile in every 1,000 miles of flight to just one tenth of a mile."

The demand for such improved accuracy and the need for a greater volume of data increase as man moves into space. Activities at the Cape seem sure to keep Earl Hatcher busy translating new and increased quantities of the data for the next several years.

Dr. Robert H. Goddard

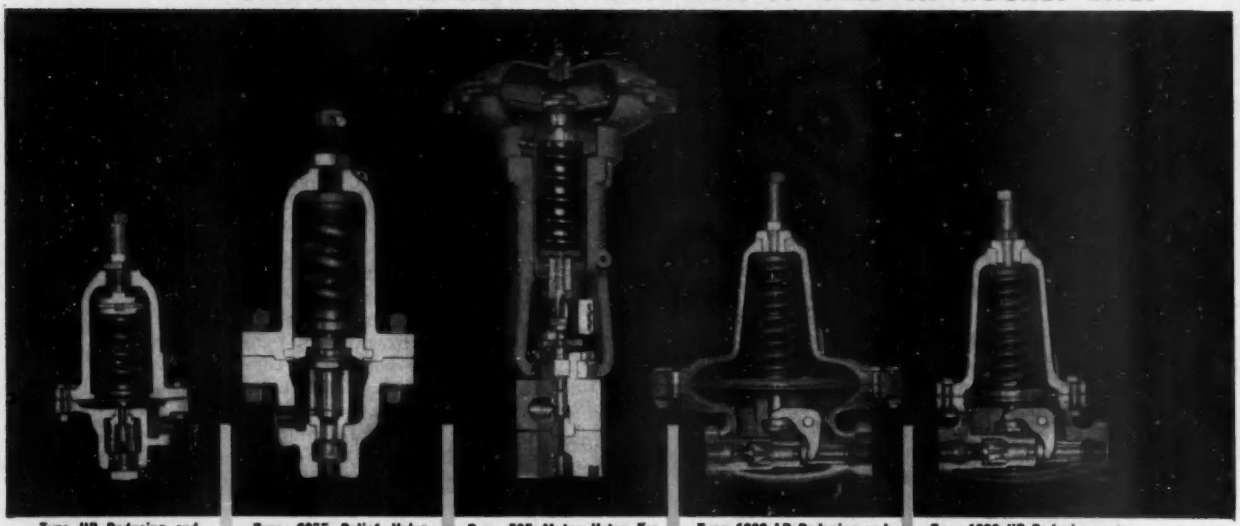
"Inventor of The Modern Rocket"

Initiated This Standard For Missile Fueling—

CONTROL VALVES

In addition to control valves for fuel and gas flow to rockets and missiles, A. W. Cash Co. manufactures a complete line of pressure regulating valves for the petroleum, chemical, pipe line and power industries. A. W. Cash Control valves are available in complete series from ¼ inch to 16 inches with screwed and flanged ends, in all castable materials, to service steam, water, air, lube oil, fuel oil, freon ammonia, tar, brine and slurries.

TYPICAL A. W. CASH CONTROL VALVES USED AT ROCKET SITES



Type HP Reducing and Regulating Valve
¼" — 1½"
Inlet Max. 3000#;
Reduced Max. 750#
Material — Bronze, Steel
Trim—Stainless Steel; Glass Filled Teflon Balanced Unit; Either Composition or Metal Seat

Type 2275 Relief Valve
½" — 2"
Max. Relief Press. 3200 lbs.
Material — Bronze, Steel
Trim — Stainless Steel Metal Seat

Type 585 Motor Valve For High Pressure Drop
½" — ¾" — 1"
Max. Initial Press. 10,000#
Material — Stainless Steel
Trim — 440 Hardened Seat, Plug. Throttling, On-Off; Micro Spline; Cv 0.008 to 3.2

Type 1000 LP Reducing and Regulating Valve
¼" — 2"
Max. Inlet 400#
Max. Reg. Press. 30 lbs.
Material — Iron, Bronze, Steel
Trim — Bronze, Stainless Steel, Neoprene or Teflon

Type 1800 HP Reducing and Regulating Valve
¼" — 2"
Max. Inlet 400#
Max. Press. 200#
Material — Iron, Bronze, Steel
Trim — Bronze, Stainless Steel, Neoprene or Teflon

Dr. Robert H. Goddard, the inventor of the modern liquid propellant rocket, found that reliable, positive acting control valves were a vital necessity for harnessing heavy gas pressures while fueling his early liquid propellant rockets. At that time, because of the unusual nature of his work, Dr. Goddard was required to make his own valves. At left is the launching site for Dr. Goddard's rocket experiments from 1930 to 1942 near Roswell, New Mexico.

Today, several types of A. W. Cash Control Valves are at work at missile launching sites carrying on the high standard of reliability initiated by Dr. Goddard.

Photos Courtesy of Mrs. Robert H. Goddard

Must Be Reliable

A. W. Cash valves are well known for their quality and low cost maintenance. When in the line they are easily accessible with all parts interchangeable. The methods of tooling and production control used in their manufacture guarantee uniformity of tolerances and dimensions of all valve components. Make A. W. Cash Co. your *one-stop source* for reliable control valves for gases, liquids and steam.

CASH SERIES 6000 DIAPHRAGM MOTOR VALVES

A. W. CASH series 6000 motor valves in sizes ½" to 2" IPS, 1" to 16" flanged for steam, gases and liquids are versatile because of the many variations available: single and double seat, "O" body, F body; six variations in top works provide for pressure ratio ranges 3-15, 5-25, 6-30, 100-300 psi, 20-200 psi, 100 to 500 psi, 500-5000 psi, and springless balance.

Single and double seat 6000 series valve plugs available are: flat seat for on-off service; linear V-Port for capacity in direct relation to travel; linear parabolic for slurries; equal % V Port; Micro-spline single seat only for precise regulation of reduced flow.

Body and trim materials used are for pressures up to 2500# and for temperatures from −425°F to +1600°F.

Series 6000 Valves are designed for converting to reverse seat action without removing valve body from the line.

Bodies available in — Iron, Carbon Steel, Carbon Moly, Chrome Moly, Nickel Steel, 304-316 Stainless, Hastalloy, Carpenter 20.

Trim — Stainless, Zirconium, Titanium, Tantalum.

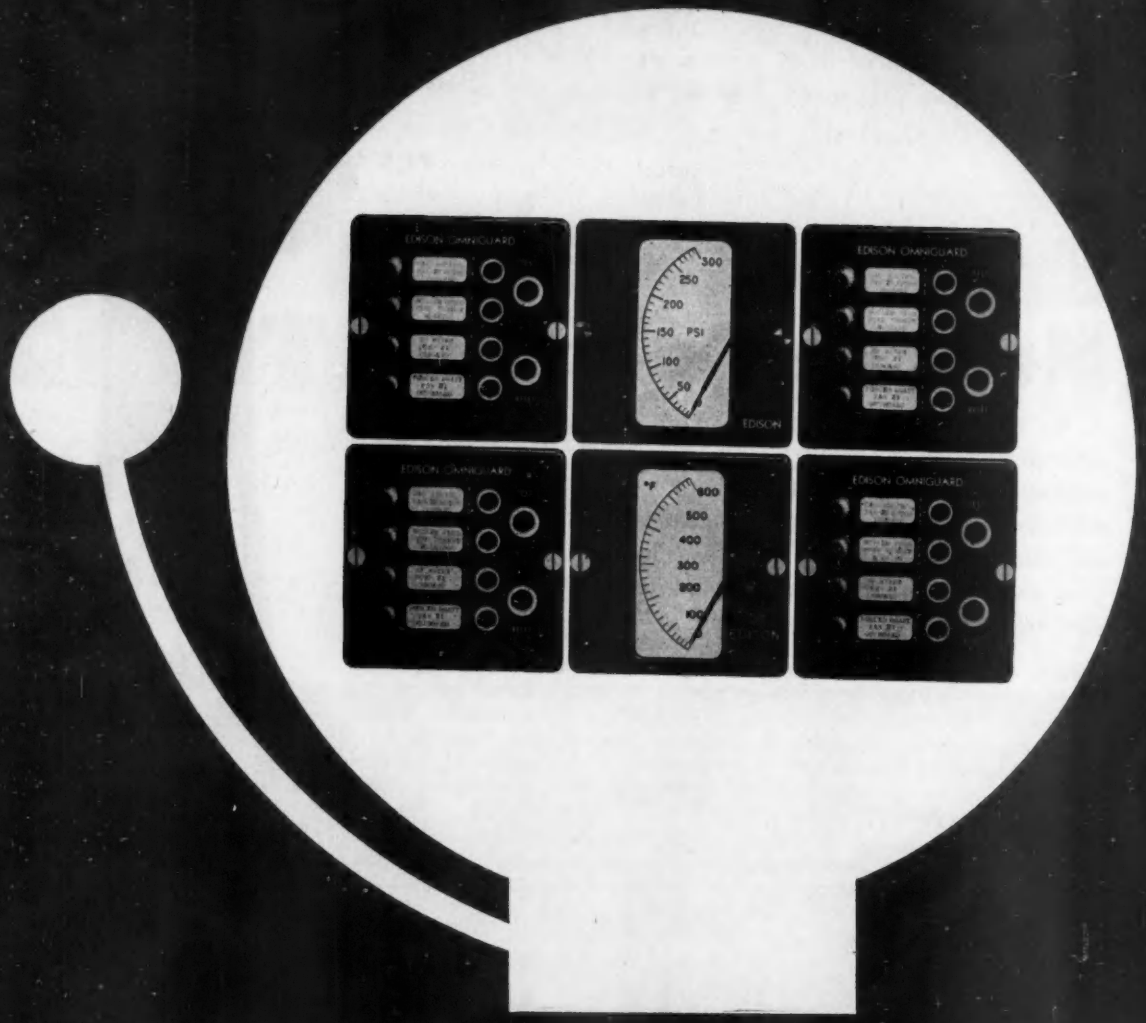
Accessories — Bellows Seal, Cooling Column, Extension Bonnet, Manual and Pilot Operation.

See A. W. Cash Control Valves At Booth No. 569—ISA Show, Chicago

A. W. CASH CO.

DECATUR, ILLINOIS

CIRCLE 20 ON READER-SERVICE CARD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250
200
150 PSI
100
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500
400
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200
100
EDISON OMNIGUARD

GUARD ALL CRITICAL PRESSURES AND TEMPERATURES WITH . . .

THOMAS A. EDISON LOW-COST, OMNIGUARD WARNING SYSTEM

Here is a versatile, highly-reliable continuous warning and monitoring system. By simply pushing a button on this panel you obtain a reading of *key pressure* and *temperature* points throughout your plant. In addition, this system provides instantaneous warning when pressure or temperature deviates from pre-set limits.

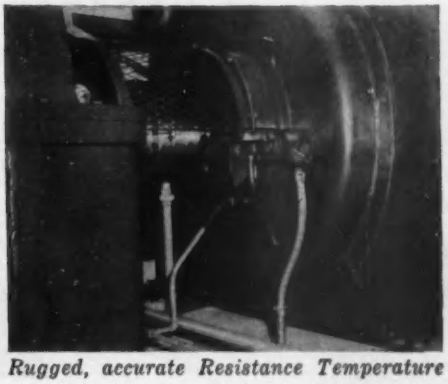
PRESSURE With the Edison Omniguard system you can monitor gas, fluid or vapor pressure. Heart of the system is a rugged accurate pressure detector which converts pressure directly to electrical resistance—requires no milli-volt conversion—no amplifier. For pressures under 60 PSI a precision capsule is the sensing element. From 60 to 3000 PSI special burdon tube elements are used.

When pressure changes, resistance varies and this deviation is transmitted to the control panel. Units operate over ambient temperatures of 32° to 150°F. Control panels are available with a wide variety of scales and are equipped with both normally open and normally closed alarm contacts to operate any type of auxiliary device or to automatically shut down machinery or process.

TEMPERATURE Edison Omniguard also provides reliable protection from overheating. You can monitor the temperature of bearings, gases and liquids in critical equipments or processes. Reliable Edison Resistance Temperature Detectors have no moving parts and give instantaneous warning when limits are exceeded. Unlike other systems which only scan, Omniguard is continuously monitoring. You can obtain exact readings of temperatures in all parts of your plant from one central control panel.

For greater flexibility and reliability each detector circuit is completely independent. If one circuit is damaged, all other circuits remain "on guard." When changes or additions are required they can be accomplished quickly and easily.

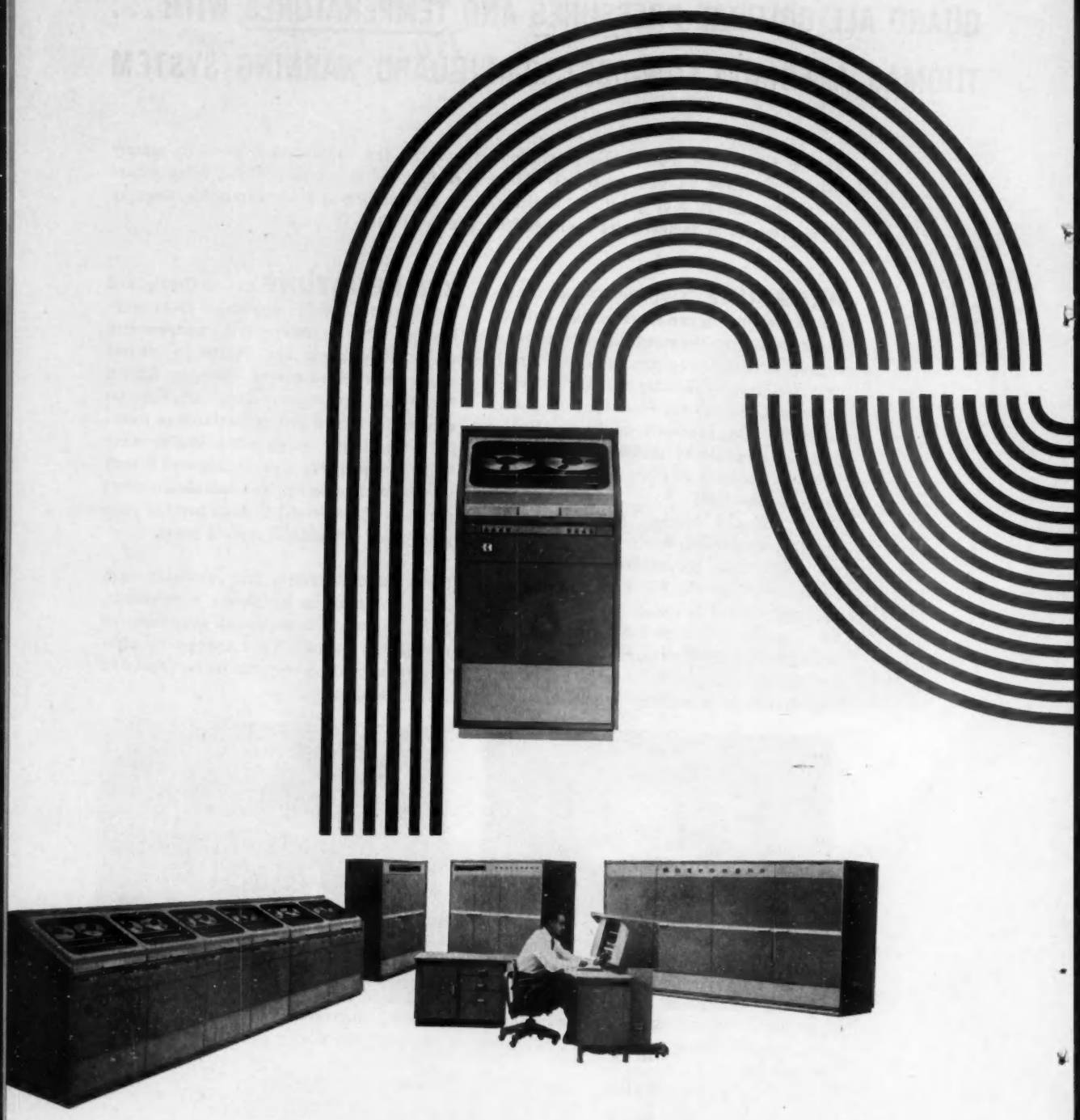
Compact, reliable Resistance Pressure Detector transmits changes in pressure to central control panel.



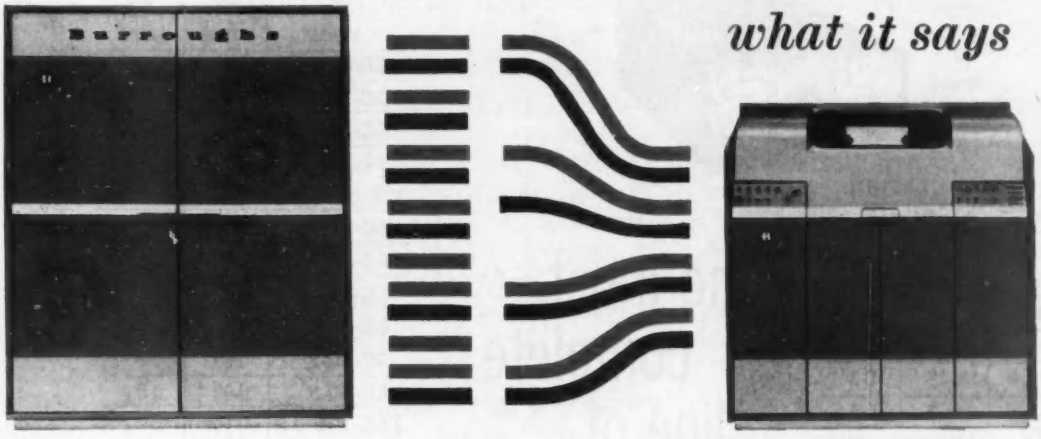
Rugged, accurate Resistance Temperature Detector guards against overheating of this motor bearing.

Thomas A. Edison Industries
INSTRUMENT DIVISION
38 LAKESIDE AVENUE, WEST ORANGE, N. J.

McGRAW EDISON



the new
Burroughs 220
high speed
printer system
prints as fast
as it thinks
and can select
what it says



Cut your volume printing jobs down to size with the new Burroughs 220 High Speed Printer System. Printing up to 1500 lines per minute, this transistorized system operates on-line directly from the 220 Computer, or can be fed off-line from one or two 220 magnetic tape files, freeing the computer for other tasks. Built-in magnetic core memory automatically stores, edits and prints out data in whatever format you need. It selects, deletes or merges information to produce neat, legible documents . . . *reports, insurance premium notices, data reduction tabulations, utility bills, labels, bank statements,* or whatever you require. All computer editing steps are eliminated, saving you valuable computer hours in obtaining printed information. This new printer system makes the Burroughs 220, already the most advanced computer in the medium price class, an even faster, more versatile data processing system for business and scientific applications. It is only a part of Burroughs' complete line of advanced data processing systems . . . all in production . . . now at work in hundreds of installations . . . and supported by a nationwide team of computer specialists. Write for Bulletin No. 5221, ElectroData Division, Pasadena, California.

Burroughs Corporation *"NEW DIMENSIONS/in electronics and data processing systems"*

CIRCLE 22 ON READER-SERVICE CARD

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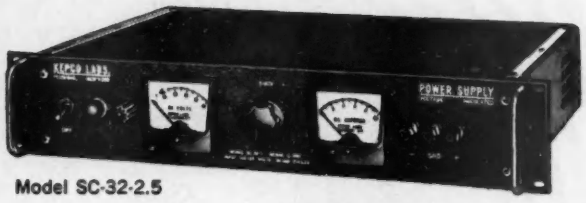
***VOLTAGE REGULATED POWER SUPPLIES**



Model SC-32-2.5

Model SC-18-2M

0.1% REGULATION STABILITY

MODEL	DC OUTPUT VOLTS	DC OUTPUT AMPS.
SC-18-0.5	0-18	0-0.5
SC-18-1	0-18	0-1
SC-18-2	0-18	0-2
SC-18-4	0-18	0-4
SC-36-0.5	0-36	0-0.5
SC-36-1	0-36	0-1
SC-36-2	0-36	0-2
SC-3672-0.5	36-72	0-0.5
SC-3672-1	36-72	0-1

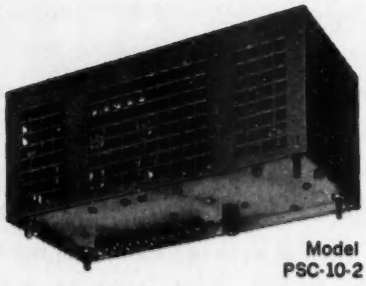
0.01% REGULATION STABILITY

MODEL	DC OUTPUT VOLTS	DC OUTPUT AMPS.
SC-32-0.5	0-32	0-0.5
SC-32-1	0-32	0-1
SC-32-1.5	0-32	0-1.5
2SC-32-1.5	0-32	0-1.5
DUAL OUTPUT	0-32	0-1.5
SC-32-2.5	0-32	0-2.5
SC-32-5	0-32	0-5
SC-32-10	0-32	0-10
SC-32-15	0-32	0-15
SC-60-2	0-60	0-2
SC-60-5	0-60	0-5
2SC-100-0.2	0-100	0-0.2
DUAL OUTPUT	0-100	0-0.2
SC-150-1	0-150	0-1
SC-300-1	0-300	0-1

the most complete line of POWER SUPPLIES

Kepco offers more than 120 standard voltage regulated power supplies covering a wide range of transistor, tube and magnetic types.

For complete specifications, write for Brochure B-591



Model PSC-10-2

0.02% REGULATION STABILITY

COMPACT PACKAGE TYPE

MODEL	DC OUTPUT VOLTS	DC OUTPUT AMPS.
PSC- 5-2	0- 7.5	2
PSC-10-2	7.5-12.5	2
PSC-15-2	12.5-17.5	2
PSC-20-2	17.5-22.5	2
PSC-28-1	22.5-32.5	1
PSC-38-1	32.5-42.5	1

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Newsbreaks In Control

● **BAILEY UNVEILS ELECTRONIC CONTROL**

Cleveland—Latest supplier to offer an electronic process control system is Bailey Meter Co. The new transistorized system, to be unveiled at the ISA show in Chicago, has been sold in the power utility industry, although no installations have been completed as yet.

● **RUSSIANS EYE TAPE TV**

Leningrad—Russians are excited about a new TV tape recorder currently under development at the Kinmash factory. First application: to record data on space flights. But the Soviets also want to use the equipment for entertainment purposes. Prototype will be ready for testing later this year (putting the Russians well behind the Ampex Corp. which has been producing such equipment for several years).

● **RECOMP TO CONTROL FURNACE**

Sweeny, Texas—Phillips Chemical Co. has installed a Recomp II, general purpose digital computer, to control burnout in hydrocarbon furnaces in the company's big ethylene plant here. The machine, built by Autonetics Div., North American Aviation, is scheduled to go on line in September. The Phillips installation was one of several sales made in late summer by the aircraft company. Autonetics will also deliver this month a Recomp II to Standard Oil of California at its Richmond (Calif.) refinery where it will serve as an operating guide computer and problem solver. Other summer Recomp II sales: Autometrics Div. of Paramount Pictures; Sanders Associates, and Stanford Research Institute.

● **HIGH SPEED COMPUTER ELEMENT**

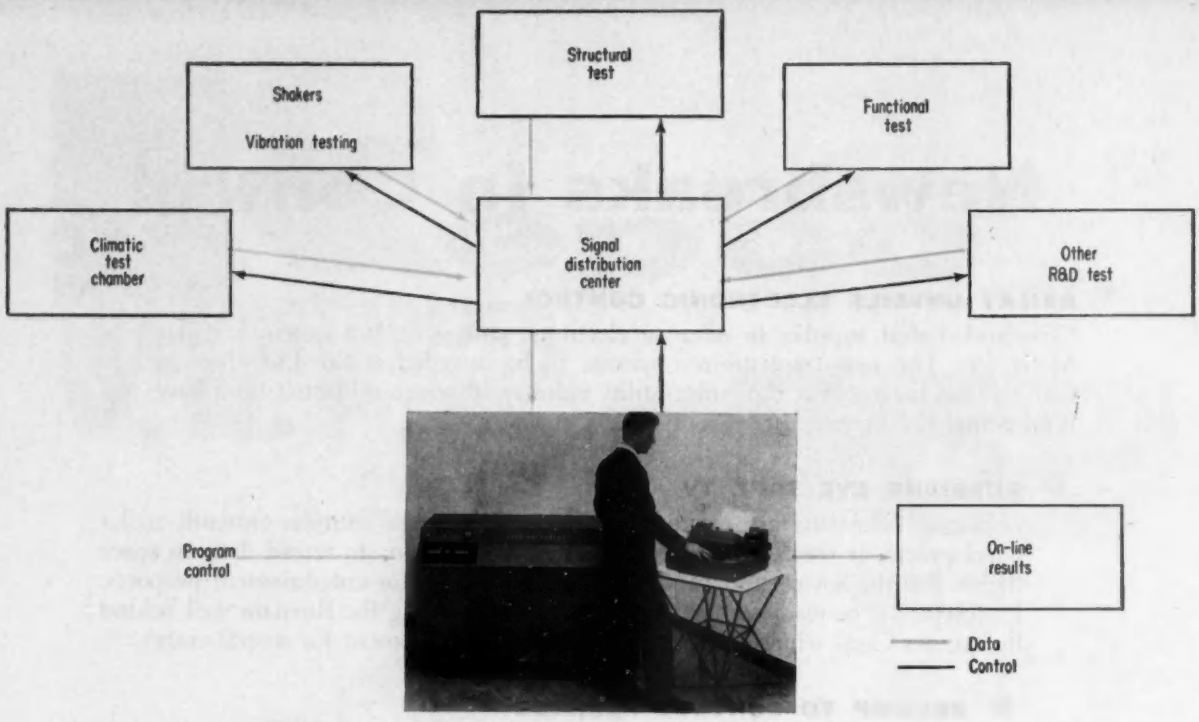
Los Angeles—BIAX, computer element made of tiny bars of ferrite material, is capable of microsec performance in both logical networks and memory arrays. Produced by Aeroneutronics Div., Ford Motor Co., new element operates on flux interference between magnetic fields, accomplished by drilling two holes in the ferrite.

● **COMPONENT SPECS UP FOR STUDY**

Dallas—To bring users and manufacturers into closer agreement on component standards will be the purpose of a special two-day session at the National Automatic Controls Conference, scheduled for Dallas, November 5 and 6. Components conference chairman, D. D. Pidhayny, Thompson Ramo Wooldridge, Inc., says the program calls for reports on proposed standards for magnetic components, hydraulic components, electromechanical components, and instrumentation.

● **IFAC PROCEEDINGS PROCEED**

New York—Dr. John R. Raggazzini, New York University Dean of Engineering who will edit the Proceedings of the 1960 IFAC Congress, reports that the proceedings will be published by Butterworth's Publications in England. Deadline for material to be in the hands of the printer is December 1, 1959. The English printer will arrange for translation of the papers and will prepare preprints of the articles as well as a collated proceedings.



Instant Data at Missile Test Facility

SALT LAKE CITY—Real time data processing will speed up missile testing at the research laboratory and environmental test complex being built at the Sperry Utah Engineering Laboratory. The Sperry control and data reduction system (supplied by The Thompson-Ramo-Wooldridge Products Co.) will connect directly to measuring and sensing elements in one or more environmental test chambers and stands. The arrangement will cut data reduction time by a factor of 250.

During testing of missile components an RW-300 computer will collect data from transducers, convert the readings to digital form, perform the required calculations to produce test results, and print out these results for immediate use. Test conditions can be altered while the test is in progress. To do this, analog and digital outputs of the system are fed back to the test stand, without interrupting the test procedure.

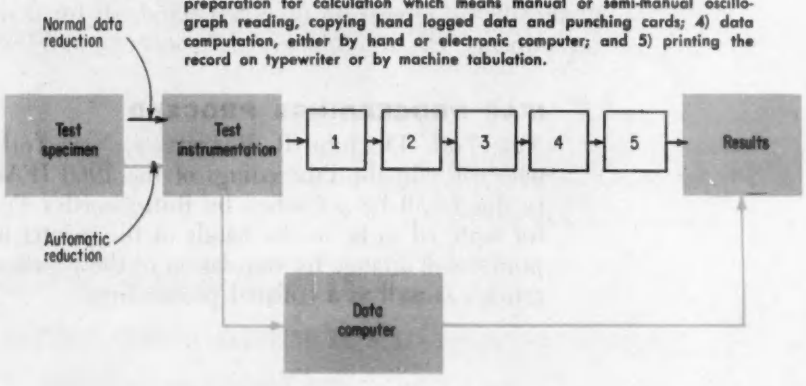
Initially, the installation will have 300 different inputs, connected to the data system, one at a time. The computer, however, can connect with as many as 320 lines, which are interconnected at a common distribution board to any number of test lines.

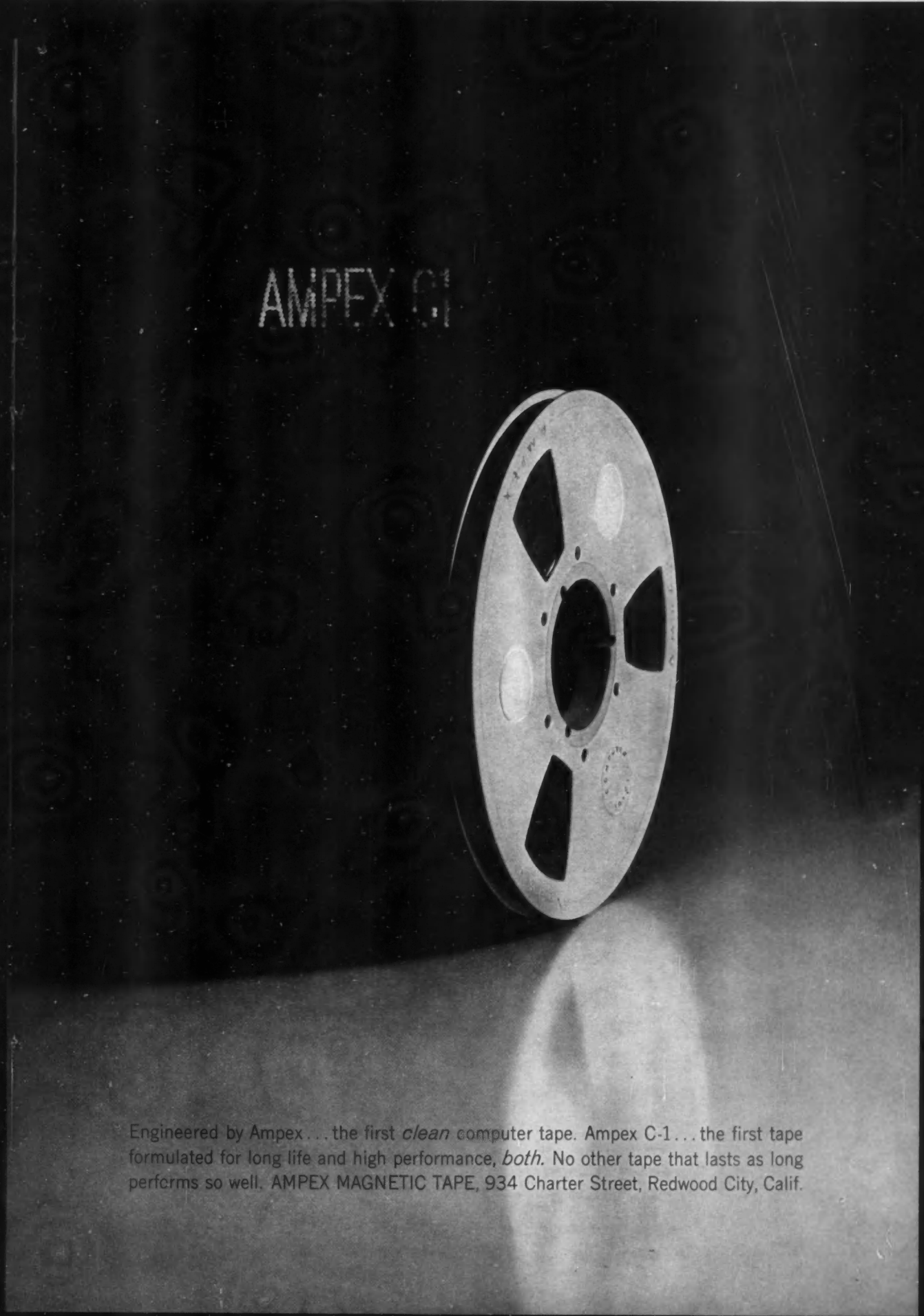
Measurements from a thermocouple, for instance, attached to a test specimen, are brought over shielded cable to the distribution board, where it is connected to the switching system of the computer. As the computer scans all inputs, the voltage from the thermocouple is converted to numerical values and stored in a specific memory cell. Directed by the program, the computer will read the memory cell at the proper time, then perform necessary scaling and averaging. Incoming voltages continually update the data so test engineers obtain continuous on-line results.

Signals from the 300 instruments—to measure a variety of variables: pressure, temperature, frequency, acceleration, length, and rotation—are piped through the distribution system into conditioning equipment, then into the RW-300's analog-to-digital converter, and finally into the computer.

In addition, information from test

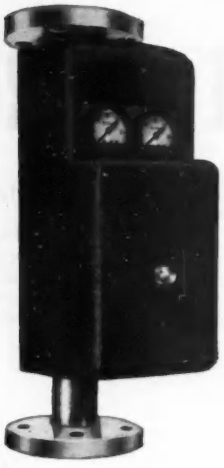
SAVINGS FROM REAL TIME DATA REDUCTION.
Here are the steps eliminated: 1) data recording, including hand logging and oscillograph reading; 2) data reduction preparation such as hand sorting and filing, oscillograph playbacks, and calibration curves; 3) preparation for calculation which means manual or semi-manual oscillograph reading, copying hand logged data and punching cards; 4) data computation, either by hand or electronic computer; and 5) printing the record on typewriter or by machine tabulation.





Engineered by Ampex . . . the first *clean* computer tape. Ampex C-1 . . . the first tape formulated for long life and high performance, *both.* No other tape that lasts as long performs so well. AMPEX MAGNETIC TAPE, 934 Charter Street, Redwood City, Calif.

ANOTHER FIRST FROM BROOKS



STRAIGHT-THRU FLOW ROTAMETER-TRANSMITTER

This is the rotameter-transmitter for all your tough fluid metering jobs. Slurries, still bottoms, Bunker oils, pthalic anhydrides, tall-oil compounds—you name it. Brooks' new armored Model 3611-MPTX with straight-thru flow has no pockets or elbows to gum-up the works. Use it for pneumatic transmission, electric transmission, or integration. However you use it, you can count on dependable operation always: Brooks' unique magnetic position converter sees to that. No blue-sky promises, these are claims we can prove. **And we will—just visit our display at the ISA: Booth No. 342-443.**

BROOKS
ROTAMETER COMPANY
959 E STREET
LANSDALE • PENNSYLVANIA

locations is acted upon by the computer to change the environmental conditions, to alter test parameters, or to adjust special apparatus. Such flexibility—adjustments on the test apparatus and measurement by almost any type of instruments—gives Sperry the capability of a universal test facility. It can handle all static or quasi-static test data, and it can measure phenomenon or test signals that can be interpreted as static or quasi-static.

• **Advantages of real time data**—Sperry test engineers expect five big advantages from real time reductions:

▶ Better test control—Because both test engineers and computer can feed back instructions to the test factility, Sperry expects to maintain better and tighter control of tests.

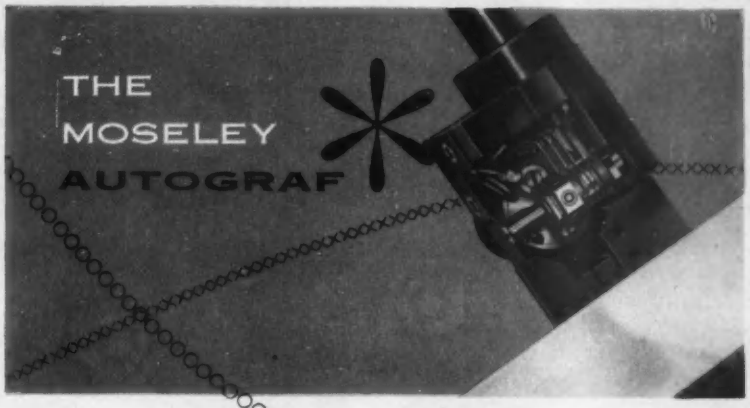
▶ Time savings—Compared to hand reduction of data (estimated at a rate of four minutes per word of data), real time data reduction, at a rate of four words per sec., can cut time or manpower by 250 to 1. (It looks as if a 1,000 to one reduction is possible, but the computer requires four men for programming and operation.)

▶ Increased information—The large number of variables that can be measured and evaluated without time-consuming data reduction will supply additional data for every test, will permit adding instrument channels that engineers "would have liked to have had, but which conventional facilities were unable to provide economically."

▶ Reduced test costs—Real time data reduction will end reruns of test (with the expense of a second setup) because insufficient or incorrect data were obtained during the original test. With the real time arrangement, results are available for review before the test set-up is dismantled.

▶ Increased flexibility—Because programs for many tests can be stored in the computer at the same time, each program independently controlled from the operator's console, an operator can move from test to test by closing a switch on the control console. The action, which connects the proper instrumentation and data reduction program, permits great flexibility in scheduling and running tests.

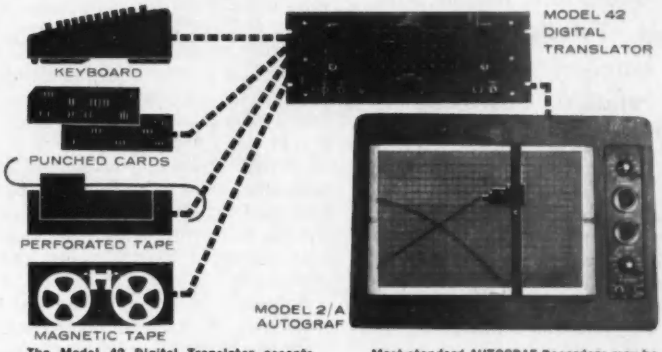
Sperry's real time data reduction facility will start operating sometime before the end of the year. First applications will be to test Sergeant missiles, the Army's surface-to-surface missile now in production. Sperry predicts that the real time data system—which cost over $250,000 for installation and training of engineers—will pay for itself out of savings in six to 12 months.



DATA REDUCTION

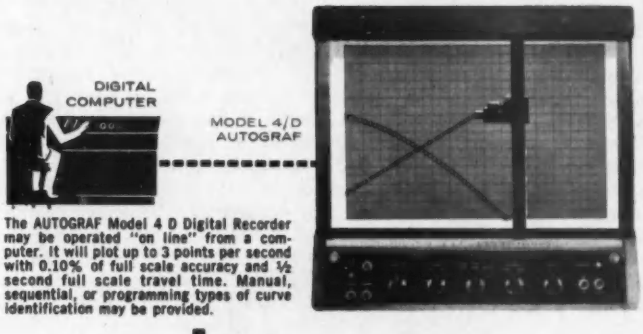
WITH AUTOMATIC SYMBOL PROGRAMMING

Digital data from almost any source may be reduced to cartesian coordinate form rapidly and accurately by means of the new AUTOGRAF Model 42 Digital Translator which may be used in conjunction with a standard model AUTOGRAF X-Y Recorder. The specially designed, high speed Model 4 D X-Y Recorder plots information directly from many digital computers.



The Model 42 Digital Translator accepts data directly from a variety of sources. Outstanding features are four decades of storage, illuminated content display, high speed, all-transistor design.

Most standard AUTOGRAF Recorders may be equipped with the symbol printer for automatic curve identification. The D-3 Character Printer provides remote programmed selection of six different symbols.



The AUTOGRAF Model 4 D Digital Recorder may be operated "on line" from a computer. It will plot up to 3 points per second with 0.10% of full scale accuracy and ½ second full scale travel time. Manual, sequential, or programming types of curve identification may be provided.

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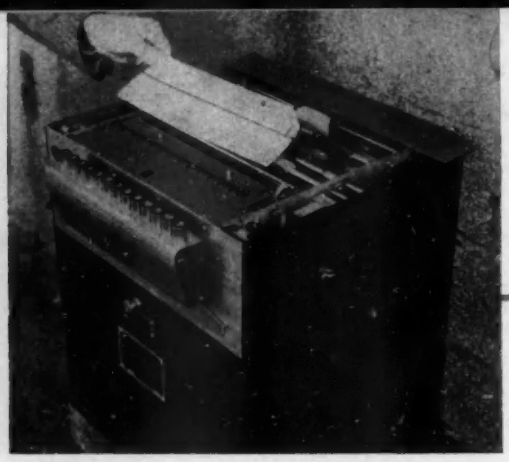
CIRCLE 25 ON READER-SERVICE CARD



TICKET ISSUING MACHINE

Relays Keep the Bettors Happy

U.S.'s biggest horse racing track opens this month with biggest Totalisator system ever installed. The key to fast, reliable operation is 8,000 relays.

NEW YORK—

When the horses start running at the new $33 million Aqueduct race track this month, bettors will place their wagers into the biggest Totalisator installation that has ever been built. The new track will have 738 pari-mutuel windows, 477 of them connected by 7.5 million feet of wire to the "tote" room located deep inside the grandstand, where bets are totaled almost instantly, odds on each horse automatically calculated, and the prices for paying off winning tickets are computed after each race. Previous biggest installation was at Santa Anita Race Track, which has 408 pari-mutuel windows.

Basic design of the Totalisator equipment, built by the American Totalisator Div. of Universal Controls, Inc., will not change, only the capacity will be increased to handle the increased number of bets expected in the machines. The Aqueduct installation will be able to handle $10,000,000 in wagers a day; it can process 1,000 bets in two seconds.

To a control engineer, one of the most interesting aspects of the Totalisator system is the extensive use of electromechanical relays to carry out the high-speed computation instead of an electronic technique. The system will use 8,000 relays—supplied by C. P. Clare Co., another Universal Controls subsidiary—and 500 rotary switches. The reason: the exceptional reliability record of American Totalisator's relay circuitry. During the 57 days of this year's summer racing meet at Belmont Track, the Totalisator equipment suffered only three minor malfunctions, and each took only seconds to correct. The three: a dirty relay contact, a broken spring, and a loose screw.

Reliability is probably the key requirement of this gear. Bad enough is the loss the track might suffer from betting cut off by disabled equipment. But even worse is the violent reaction of would-be bettors who are unable to place their wagers. Frustrated bettors have been known to tear down pari-mutuel windows when the betting machinery failed.

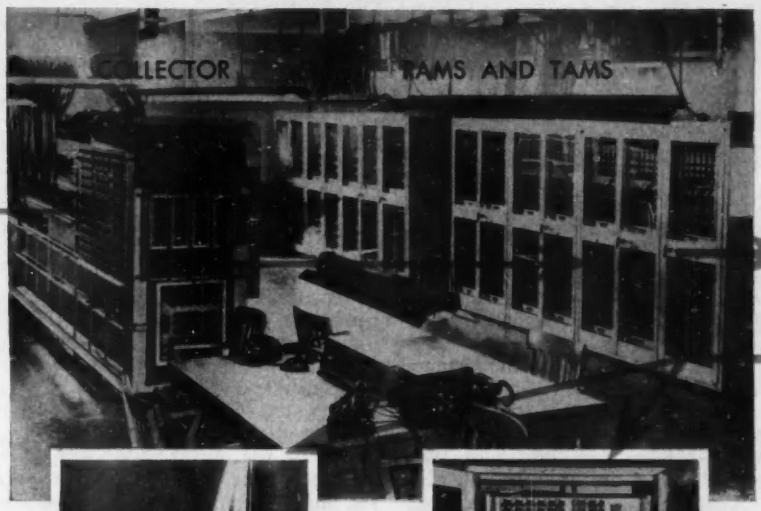
• **Starts at the window**—The Totalisator system (see diagram) starts at the ticket issuing machine in the pari-mutuel window. Betting proceeds for one race at a time, and each window is designated to receive only one type of bet, for example, $2-to-win. By pushing the button associated with a horse's number on the ticket issuing machine, the seller sends a pulse to the tote room where it is received in the collector frame, then routed to one of the three adding machine bays (each pool—win, show, and place—has its own bay).

Each group of four ticket windows is connected by a permanent cable to a main distributing frame in the tote room to simplify the wiring. A portable cord, one for each ticket machine, then connects the main distribution frame to an intermediate distribution frame. The cord may be plugged into any one of 17 betting channels, depending on the values assigned to its associated ticket machine. The channels: 2, 5, 10, 50, or 100 dollar bets to win, to place, and to show and a $6 and a $15 combination bet (win, place, and show all on one ticket).

Next step in the link is the collector. Each cord plugged into the intermediate frame is connected to an individual collector. The signal from the seller in the ticket window tells the collector that this machine wants to place a bet. The collector then completes the circuit for the ticket machine through the proper adding machines. Operation of the betting relays in the adding machines causes the rotation of rotary-type stepping switches, which, as they turn to totalize the bets, send a signal back to the ticket machine to allow the ticket to be printed.

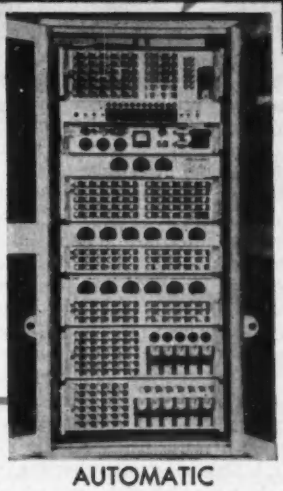
There are two kinds of adding machines, known as TAMS and RAMS, identical in design. The TAMS, three in number, are *Total Adding Machines*; one keeps a running total of all bets to win, another all bets to place (finish second) and the last one, all bets to show (finish third). The RAMS, *Runner Adding Machines*, keep a total of the amount of money bet on each horse to win, to place, and to show. There are three RAMS

TOTE ROOM



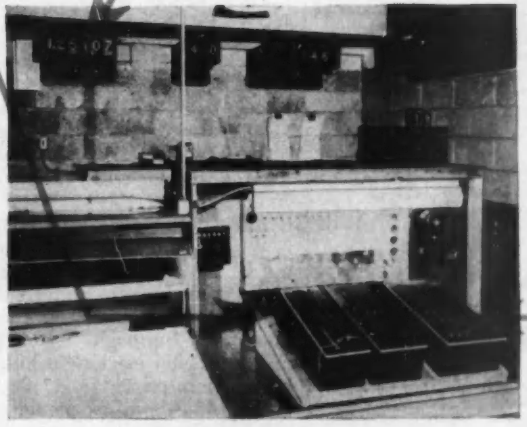
INFIELD BOARD

AUTOMATIC
OBSERVER



AUTOMATIC
ODDS
CALCULATOR

ODDS DESK



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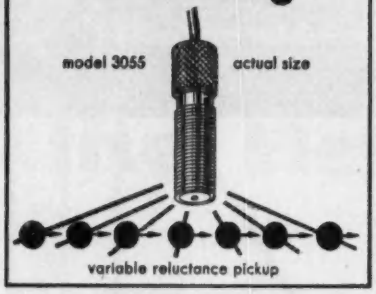

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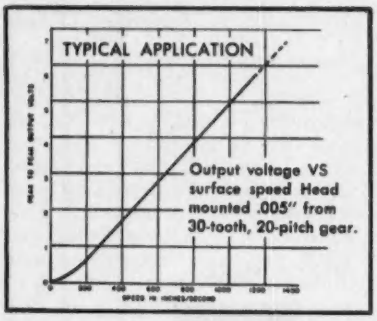

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CIRCLE 26 ON READER-SERVICE CARD

Relays click as bets flow...

(a win machine, a place machine, and a show machine) for each horse number. After the bets are registered, a pulse is sent from the adding machine (back through the collector frame) to the ticket machine, releasing the ticket. The ticket is not released until the bet is recorded in both the total and runner adding machines.

Totals in the various adding machines are read out every ninety seconds to the infield board where the spectators can see the amount of money bet in each pool and the amount bet on each horse in each pool. The infield board serves as the memory for the system. All further operations of the Totalisator system are made by "reading" the infield board. Even if the board is in error, it is what the betting public sees.

• **Automatic odds**–From the board, the win pool totals and win horse totals are read into the automatic odds calculator, an analog computer, and the automatic observer which shares a line with the odds machine. The odds unit is a wheatstone bridge type of computer which determines the percentage of the betting going to the state for taxes and to the track for management fees and calculates the odds on each horse based on the remainder. The automatic observer, a special purpose electric computer, checks the figures on the board by putting in the pool total as a minus and then adding the amount bet on each horse. If the total does not equal zero, an alarm sounds in the tote room warning the operators that there is a discrepancy.

Next door to the tote room, which is run by personnel from American Totalisator Div., is the calculating room run by the track's mutuel department. In the calculating room at an "odds desk", an operator checks the results turned out by the automatic odds calculator, and posts the odds on the infield board and auxiliary boards.

Also in the calculating room is a price computer which calculates how much the track must pay for first place, second place, and third place after the race is run. The price computer is a Burroughs E102, general purpose digital machine, whose input information comes from the infield board and whose programming unit has been changed to handle the specific problems of racing.

The pinboard programmer of the conventional E102 has been replaced by a keyboard. The normal program in the machine is for a standard finish. But if something out of the ordinary happens in a race, such as a dead heat (tie) for first place, the operator can punch in a special program to automatically consider the unusual conditions. Prices to be paid are computed even before the judges have completed their review of the finish (in New York, for example, all race finishes are photographed whether they are close or not). Prices are posted on the infield score board as soon as the judges okay the order of the finish, and make the race official.

• **Place your bets**–Here's how the system would work to handle a two dollar bet on horse number seven in the first race. After finding a $2 win window (say window number 68), the bettor asks the seller for a ticket on Number Seven. The seller pushes button number seven on the ticket issuing machine keyboard. In the win collector, two relays connected to window number 68 are closed, these in turn actuate four relays in the win bay of the adding machines, two relays in a TAM and two in a RAM. In both, the first relay merely drives the second relay which draws additional power to drive the rotary stepping switch that totalizes bets.

In the adding machine, there are 12 rotary switches. Seven of these can accept bets directly from the adding machine relays–three $2 switches, a $5, a $10, a $50, and a $100. The remaining five switches are carry switches: a $2, $10, $1,000, $10,000, and $100,000 carry.

Any combination of $2 bets placed in the same adding machine (adding to what was previously recorded in that machine), totaling $10, will operate the $2 carry switch. That means that the $2 carry switch actually records units of $10. Any combination of $2, $5, and $10 bets, totaling $50, will operate the $10 carry switch, which records units of $50. And a combination of bets totaling $100 operates the $100 rotary switch.

The $100 switch is interlocked so that it can accept either $100 bets or carries from the $50 rotary bet switches. When the $100 switch has $900 recorded on it, the next $100 bet, or carry, will step the $1,000 switch as well as the $100 one. If the $100 and the $1,000 switches are both on their ninth position, the next $100 bet, or carry, will step the $100, $1,000, and $10,000 switches. The

$100,000 rotary is stepped in the same manner.

Total amount bet into each adding machine is carried, or stored, on the banks of the rotary switches. To obtain indications for the infield board, the rotary switches are read. For the units designation, the board reads four rotary switches: the three $2 rotary and the $5 rotary switches. For tens indication, five rotary switches are read: the $5, $10, $50 bet and the $2 and $10 carry rotary switches.

As soon as runner and total rotary switches have moved, a signal is transmitted from the adding machines back to the ticket issuing machine. The returned pulse rotates a printing head to print out the ticket; rotation of the head actuates three mechanical counters: a runner, a total and a cumulative counter—which serve as backup for the electromechanical system. Total time for the issuance of our ticket: less than one second.

• **Checkout procedure**—Each day, about 90 minutes before betting starts, the American Totalisator crew at the track, normally about 20 people, checks out the equipment completely. First, with routining equipment, they program into the Totalisator bets totaling $101—automatically placed 110 times on each horse to win, place, and show. This checks out the adding equipment and the infield board.

Next, every ticket machine in the plant is set simultaneously on the same horse to win, and the bets are held up (by turning off the power) until all keys are operated, so they come crashing into the collectors at the same instant. The collector routes them to the proper TAMS and RAMS. The "crash" procedure is then repeated for every horse to win, to place, and to show. If the equipment can take this treatment, it will be able to handle any random occurrence of bets during betting period.

The infield (and auxiliary) display board consists of a large number of individual lamp units, each has 24 lamps which are controlled by the contacts of five relays. The operation of any two of the five relays will illuminate one number or digit. If the wrong relay is closed, the wrong number will appear; if only one relay closes, an incomplete number will appear; if an extra relay closes, the board will be "Chinesed", unreadable.

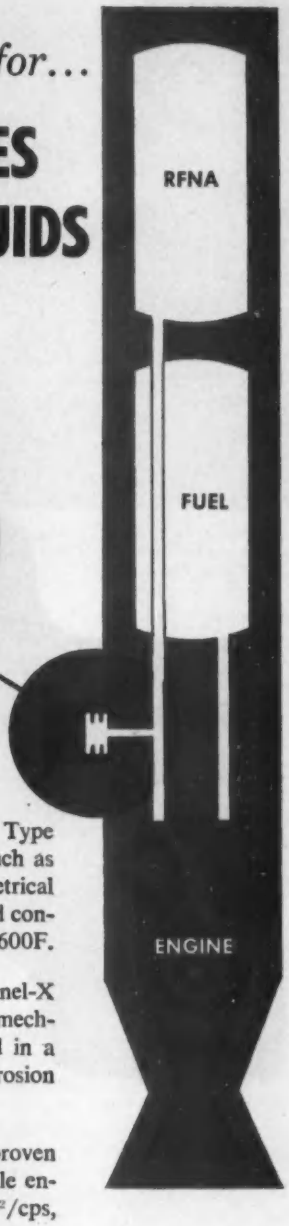
Probably the next big step will be a self service ticket issuing machine which will accept currency and issue tickets. American Totalisator hoped to have prototype equipment on test at tracks this summer, but the company fell behind schedule. Currency reading machines are being tried at trotter tracks now.

—Lewis H. Young

Pressure Potentiometers for...

HIGH TEMPERATURES and CORROSIVE FLUIDS

Type P103
Pressure Potentiometer
shown ¾ size



New Trans-Sonics* Pressure Potentiometers, Type P103, measure pressures of corrosive fluids such as red fuming nitric acid (RFNA) and unsymmetrical dymethylhydrazine (UDMH) for telemetry and control applications at ambient temperatures up to 600F.

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Flexibility of installation is assured by small size and light weight. Dimensions are 1⅞" diameter by 1⅞" long. Weight is only 6 ounces. Standard ranges are 0-100 and 0-150 psia . . . other ranges to special order. Write for Technical Bulletin P103 to Trans-Sonics, Inc., Dept. 11, Burlington, Mass.

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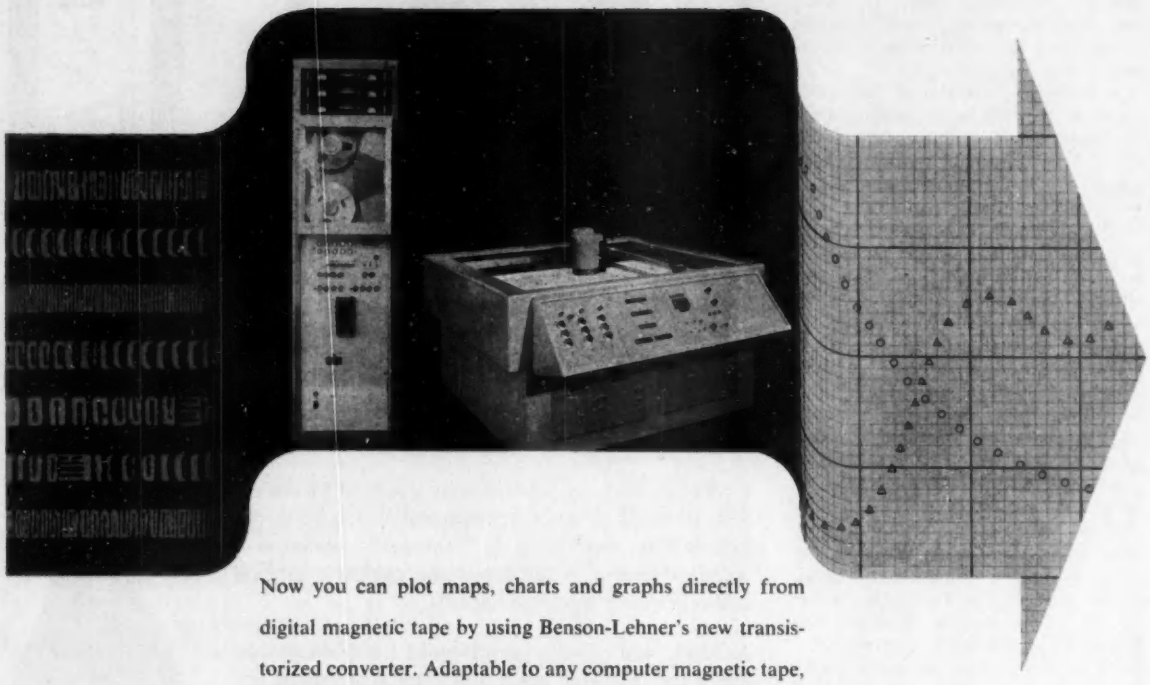

Now you can plot maps, charts and graphs directly from digital magnetic tape by using Benson-Lehner's new transistorized converter. Adaptable to any computer magnetic tape, it eliminates the need for conversion to punched cards and will more than double the speed of the Benson-Lehner ELECTROPLOTTER you already own! By converting digital tape data to an analog voltage, it provides a compatible input for many automatic graph plotters and X-Y recorders. Write now for information or to have an applications engineer help establish your exact requirements.

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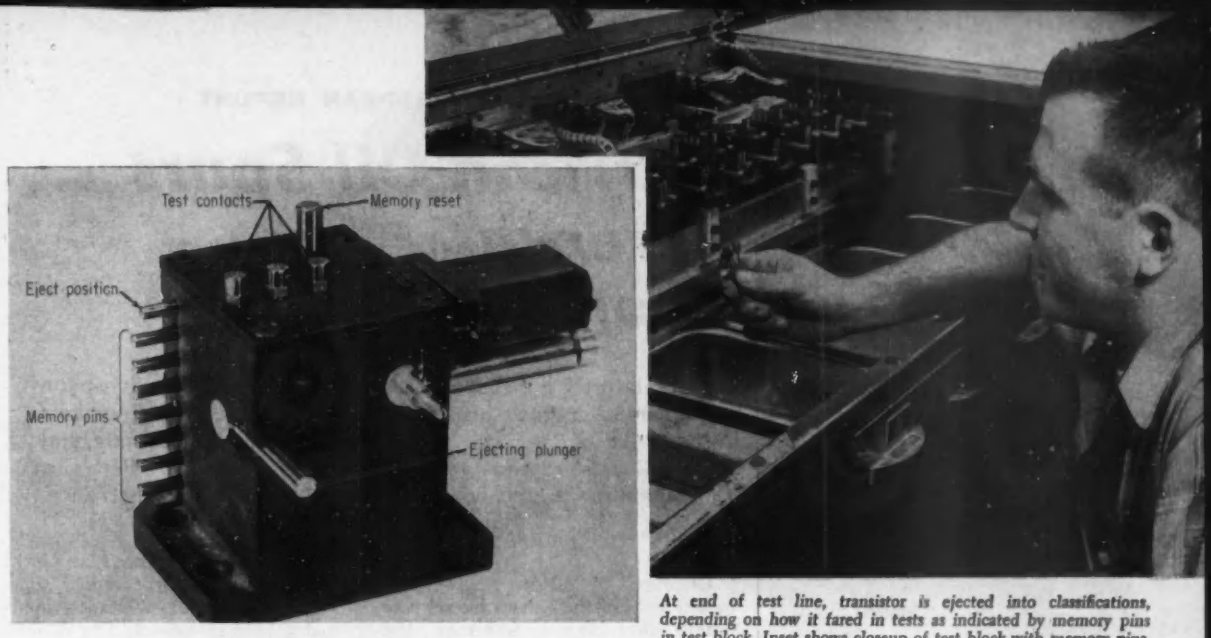

At end of test line, transistor is ejected into classifications, depending on how it fared in tests as indicated by memory pins in test block. Inset shows closeup of test block with memory pins.

FAST Tests and Sorts Transistors Fast

DALLAS—

Texas Instruments, Semiconductor Components Div., one of the major suppliers of transistors, is manufacturing transistor test and sorting equipment to check TI's own products. The latest development is FAST, Facility for Automatic Sorting and Testing, a sleek looking machine that spews out 1,900 transistors an hour.

FAST represents a significant improvement over TI's first commercial transistor sorter, CAT (CtE, April '59, p. 40):

- ▶it can measure transistor parameters at test frequencies as high as 2.5 megacycles. Up to 12 parameters can be checked, depending on the type of transistor being tested.
- ▶it can handle three specific families of transistors which are classified into five different types.
- ▶a self-contained memory built into each test block remembers and retains test parameter results for subsequent readout. Results can also be punched onto paper tape.
- ▶Supply voltages are continuously monitored, between test cycles, each station is automatically checked for calibration.

The new machine is built with two rows of six test stations. Test blocks are fixed to a movable chain which is driven past the test stations by a hydraulic drive system. Each station is really a self-contained unit with an individual timer and trip circuitry; only power supplies are common.

• **Built-in pin memory**—One of the key parts of the test block is the built-in mechanical binary memory. Eight metal pins—each set-up for certain specifications—can be punched in by signals initiated at the test stations. The pins indicate what's been happening to the transistor in that test block. For example, if a transistor is rejected, it is immediately and automatically ejected out of the test block, and the top pin is punched. As long as this pin is inset, none of the succeeding stations in the line will test the empty block.

During a test, each block contains a single transistor. The block is stopped at the test station for about one second and a half; the block moves to the next station in about half a second.

As the test block moves into position at a station, it closes a Microswitch activating a tube-driven RC time constant circuit which controls the length of time the transistor is held in the test condition. At the end of the test cycle, air-operated solenoids set various pins on the rear of the test block. If the unit is out of specification, the transistor is rejected and ejected, while a counter keeps track of the number rejected.

• **On-line calibration**—After the test cycle, the RC time constant circuit returns the test set to the calibration state. A monitoring circuit checks the calibration. Here's how. The monitoring circuit is made up of operational amplifiers connected as summing amplifiers. All supply voltages are fed to the summing junction of the operational amplifier and the output adjusted for zero. Any change in the sampled voltages will cause an unbalance at the summing junction, and the unbalance is amplified to activate a relay which lights a warning light on the test set and shuts off the machine drive mechanism.

When a test block has passed all of the test stations, it moves to the readout positions where a series of Microswitches sense the location of the memory pins. What pins are inset determines the classification of the transistor. After the pins are read, a solenoid ejects the transistor into the proper classification bin.

FAST also has output provisions to operate a digital voltmeter and an eight-hole paper tape punch. Actual parameters can be read, if desired, or recorded on paper tape.

At each classification bin, counters maintain records of how many units are being put into each group. Thus the two operators can keep track of how many are going into each classification and how many are being rejected at each station.

—Kemp Anderson
McGraw-Hill News

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CIRCLE 29 ON READER-SERVICE CARD

African Oil Spurs French Control Makers

Accelerated business in the oil industry and the European Common Market are encouraging French control makers to strike out on their own. Native developments may end or diminish French reliance on U.S. licensing. Here's a roundup of what's happening in the control field in France.

PARIS—Discovery of oil in the French-owned areas of the Sahara Desert may supply the biggest incentive the French control industry has ever received. A rise of French-owned petroleum and chemical companies, coupled with the import tariffs and quotas of the European Economic Community (CtE, July '59, p. 75), is inducing French control makers to launch their own developments. The trend threatens to cut U.S. makers' share, currently about 38 percent, of France's $24 million a year instrument and control imports. And, even more significant, it may reduce the return from U.S. licensing, which has been responsible for much of France's domestic $62 million a year control industry.

In the post-war years since 1945, French industry has been bedeviled by a combination of recurrent economic difficulties. Funds for research and development were limited, markets were poorly developed, and import restrictions discouraged bringing in completed equipment. Under these circumstances, French control makers were forced to rely on licensing agreements—most of them with U.S. makers. Now the tide may be turning.

• **Active SEA**—Ten year old Societe d'Electronique et d'Automatisme is a typical example of the new trend. The company has three divisions which make analog and digital computers, industrial controls, and aircraft simulators, the latter on license from Curtiss-Wright Corp. of New Jersey.

SEA is already a leader in the analog field in France. The company has sold over 100 installations of its standard 12-amplifier L-2 machine, costing $4,000, and its larger 24-amplifier P-2 machine. SEA has just developed a $3,000 transistorized repetitive desktop analog computer which is said to operate with an accuracy of two percent. Program connections to the 12 amplifiers are made on a sub-desk below the operating panel. A change-over switch gives the user a choice of repetitive frequencies of 2 or 5 cps for recorded or visual solutions.

In the component area, SEA has made a major contribution: a printed circuit motor, which attracted a lot of attention when it was displayed at the US's IRE show last March. The unusual motor has a torque-inertia ratio almost four times that of a conventional machine, lends itself particularly to control applications that do not require continuous full load output. When connected to a 50 cps supply, its short response time of 4 milliseconds allows it to oscillate at the supply frequency simultaneously with delivering high starting torques. It can do this because its armature is a thin glass disc on which printed conductors form a multi-polar winding.

For the printed circuit motor, SEA has reversed the traditional U.S.-French licensing approach; it has

Transistorized analog computer made by Societe d'Electronique et d'Automatisme.

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CIRCLE 30 ON READER-SERVICE CARD

Revised Issue of the MUIRHEAD SYNCHRO BROADSHEET

This revised issue of the Muirhead Synchro Broadsheet is available to all those interested in servo engineering. Prepared in tabular form for easy reference, it presents the brief specifications of Muirhead Control Transmitters and Receivers; Motor Tachometers and Tachometer Generators; Two-Phase Servomotors and Resolvers and Linvars in Standard Synchro frame sizes.
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CIRCLE 31 ON READER-SERVICE CARD

WHAT'S NEW

. . . static switching is selling well in France . . .

licensed its printed circuit motor to a U.S. company, Printed Motors, Inc.

• **Popular static switching**—Four French companies have already developed their own static switching systems. A fifth, Schneider-Westinghouse, is manufacturing Westinghouse's Cypak under license. Two of the French systems use magamps, the other two are transistorized.

Alsthom of Paris offers a transistorized "Logistor" system in which a single NOR element performs all logic functions. Other elements include an input amplifier, time delay unit, a visual signalling unit and a 50-watt output amplifier. The system's response time is one microsec. Alsthom has already installed its system in steel rolling mills and blast furnaces, has sold 15 more systems, yet undelivered.

Another transistorized static system has been developed by SDEE-Thomson Houston. It consists of four basic units: a multi-input AND, control unit, time delay, and a power amplifier, which is rated at 100 watt peak power for one sec or 40 watts continuous. The logic units are transistorized flip-flops; adjustable triggering levels control sequencing.

SEA has espoused the magamp approach to static switching. The company has already sold 12 installations of its Logimag system for such diversified applications as coal mine conveyors and butane and pentane automatic bottling plants. The basic Logimag unit, operating from a 50 cps, 8.2 volt supply, is a halfwave magnetic amplifier; double control windings allow direct or indirect inputs. To increase the 100 milliwatt logic signal to operate final contactors, SEA offers a range of power amplifiers up to 200 watts output. Magamp delay units provide delay times up to 40 sec.

The Relaistat system, marketed by the Societe des Servomecanismes Electroniques, is being tested by French railroads to control contactor circuits of electric locomotives. Railroads are also investigating the use of Relaistats to detect wheel slip and overspeeding. For wheel slip detection, tachogenerators on each wheel are connected in series opposition. Any resultant voltage, caused by one axle slipping is amplified and operates an automatic track sanding device. For overspeed detection, adding the tachometer outputs over a preset limit cuts off the main motor.

—Derek Barlow

CLEVITE . . . . . DIFFUSED SILICON RECTIFIERS

TECHNICAL DATA:			
Diode Type	Maximum DC Inverse Operating Voltage (volts)	Maximum Average Forward Current @ 25°C (ma)	Maximum Forward Voltage Drop @ 25°C (volts @ ma)
1N645	225	400	1.0 @ 400
1N647	400	400	1.0 @ 400
1N649	600	400	1.0 @ 400
1N677	100	400	1.0 @ 400
1N681	300	200	1.0 @ 200
1N683	400	200	1.0 @ 200
1N685	500	200	1.0 @ 200
1N687	600	200	1.0 @ 200

Clevite offers silicon rectifiers designed for maximum reliability in the severest military and commercial applications.

Check these features:

- **HIGH DISSIPATION — 600 mw**
- **SUBMINIATURE GLASS PACKAGE**
- **HIGH VOLTAGE — up to 600 volts**
- **HERMETICALLY SEALED**
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For details, write for Bulletin B217A-3

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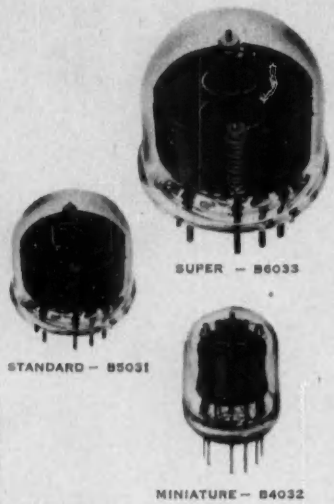
CIRCLE 32 ON READER-SERVICE CARD

Burroughs NIXIE® | NUMERICAL READOUT TUBE



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DYNAMIC LIFE – 25,000 HOURS

STATIC LIFE – 5,000 HOURS (on one number)

ALL ELECTRONIC IN-LINE READOUT CONTAINING TEN DIGITS "0" THRU "9"

The Ultra Long Life Nixie Tube offers increased life for those applications requiring continuous display of one of the ten characters for extended periods of time. Under these stringent conditions a minimum of 5000 hours life on one numeral can be expected. Where the display is changed sequentially, even as infrequently as every 100 hours, life in excess of 25,000 hours can be expected.

NIXIE Tube Exclusive Features:

- ALL ELECTRONIC
- LOWEST COST
- LOWEST POWER
- LIGHTEST WEIGHT
- MOST READABLE FOR NUMBER SIZE
- SMALLEST VOLUME AND NUMBER SIZE
- MAXIMUM TEMPERATURE, SHOCK AND VIBRATION SPECS
- AND NOW, LONGEST LIFE

ANOTHER ELECTRONIC CONTRIBUTION BY
Burroughs Corporation
ELECTRONIC TUBE DIVISION
Plainfield, New Jersey

CIRCLE 33 ON READER-SERVICE CARD

Control Users' Foreign Investment Up

U. S. Industry's capital spending plans for plants built abroad are on the increase, as reported in a new McGraw-Hill survey; spending to rise 5 percent in 1959 with equal plans for 1960.

Control makers with an eye on rising export sales (CtE, August, '59, p. 61) heard more good news last month. American manufacturing and petroleum companies plan to spend $2,144 million on new producing facilities outside continental United States in 1959 and an almost identical amount in 1960. This represents a 5 percent increase over 1958, still below the record $2.5 billion invested abroad in 1957.

A survey, conducted by the McGraw-Hill Dept. of Economics, was the first comprehensive inquiry into plans of American firms for capital spending overseas; it also compiled figures on expected exports and sales of foreign subsidiaries. The investment figures, which are closely related to instrument and control sales, cover the capital spending plans only of those participating in the survey and reflect the situation as of July. McGraw-Hill economists estimate, however, that the companies reporting will account for three-fourths of annual U. S. capital expenditures overseas.

• **Petroleum leads**—Petroleum companies in the survey plan to invest $1,186 million in new plants, equipment, and property abroad this year and will up their spending to $1,246 million in 1960. This industry is spending more than all manufacturing industries (excluding petroleum refining) combined. These plans for 1959-60 still run well below the 1957 high of $1,575 million, when U. S. petroleum companies—influenced by the curtailment in oil from the Middle East resulting from the Suez-crisis—made unusually large investments in Latin America.

• **Manufacturing sets a record**—Although comparable data is not available for the years before 1957, that year probably saw the peak for manufacturers' overseas expenditures at

FOREIGN CAPITAL EXPENDITURES BY AMERICAN COMPANIES

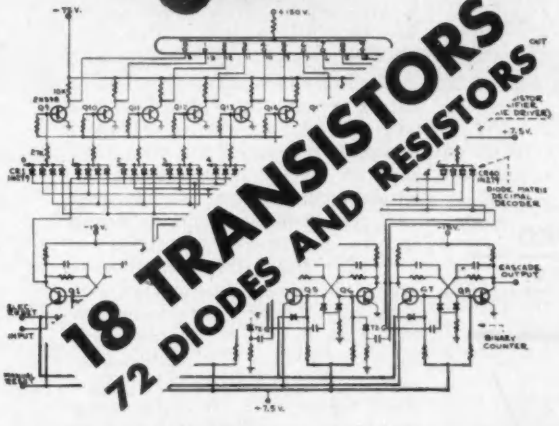
Millions of Dollars

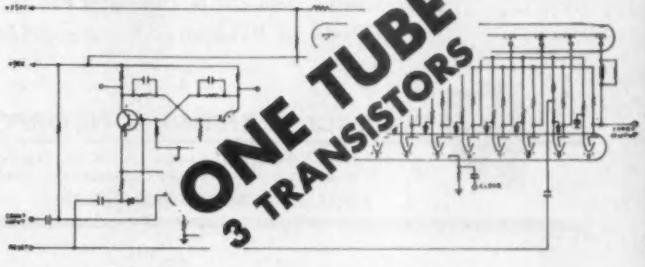
INDUSTRY	1957	1958	1959	% Change 1958–59	1960
	Actual		Planned		Planned
Primary Metals*	$155.2	$127.7	$132.6	+ 4%	$96.2
Machinery (Incl. Electrical)	181.0	176.0	208.2	+18	251.1
Transportation Equipment Including Autos	218.6	109.3	209.9	+92	186.8
Other Metalworking	30.3	21.5	33.3	+55	26.3
Chemicals	147.5	178.5	203.5	+14	175.0
Paper	60.5	29.6	39.1	+32	25.0
Rubber	61.5	51.0	69.4	+36	67.3
Stone, Clay, & Glass	22.1	25.0	18.2	−27	12.0
Food & Beverages	39.3	34.2	31.5	− 8	37.2
Misc. Manufacturing Including Textiles	13.4	8.8	11.4	+29	11.4
ALL MANUFACTURING	929.4	761.6	957.1	+26	888.3
Petroleum	1575.1	1275.8	1186.5	− 7	1245.8
Manufacturing & Petroleum	2504.5	2037.4	2143.6	+ 5	2134.1

* Includes some mining companies

Note: Dollar figures reflect only expenditures of cooperating companies. These companies account for approximately ¾ of annual overseas expenditures of U. S. manufacturing and petroleum companies.

New MINIATURE BEAM SWITCHING TUBE ELIMINATES transistor HYSTERISTOR*





ALL TRANSISTOR DECADE COUNTER WITH NIXIE® TUBE READ-OUT — Since transistors are "on-off" or binary devices, they require complex and multi-component circuitry to perform simple electronic distributing, switching, counting and other decimal functions.

***Hysterical Total Use of Transistors, Resulting in Multi-Component Unreliability.**

MINIATURE BEAM SWITCHING TUBE DECADE COUNTER WITH NIXIE TUBE READOUT — One Miniature Beam Switching Tube eliminates 90 transistors, diodes and resistors. The result is a Beam Switching Tube-Transistor circuit which utilizes the **best features** of both components.

Write for COMPARISON CHART WHICH OUTLINES BEAM SWITCHING TUBE ADVANTAGES IN SIZE, WEIGHT, POWER, COST, TEMPERATURE, SHOCK, VIBRATION, LIFE AND RELIABILITY.

ELECTRONIC TUBE DIVISION

ABSOLUTE PRESSURE INDICATOR
...For Precise Vacuum Work

Accuracy:	1/300 of full scale
Sensitivity:	1/500 in *all* ranges
Ranges:	0-50mm Hg. 0-100mm Hg.
	0-200mm Hg. 0-410mm Hg.
	0-800mm Hg. 390-800mm Hg.
Dial Sizes:	2¾" or 6" diameter for all ranges

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CIRCLE 36 ON READER-SERVICE CARD

WHAT'S NEW

. . . instruments and controls buck the tide . . .

$929 million (for the companies reporting in the survey). A 26 percent increase over 1958 and a new high should result in 1959 with the participating firms planning to spend $957 million. But a decrease to $888 million is expected in 1960. These plans may be altered substantially, though, since several surveyed companies indicated they were contemplating investment in new facilities abroad but had not yet made definite plans.

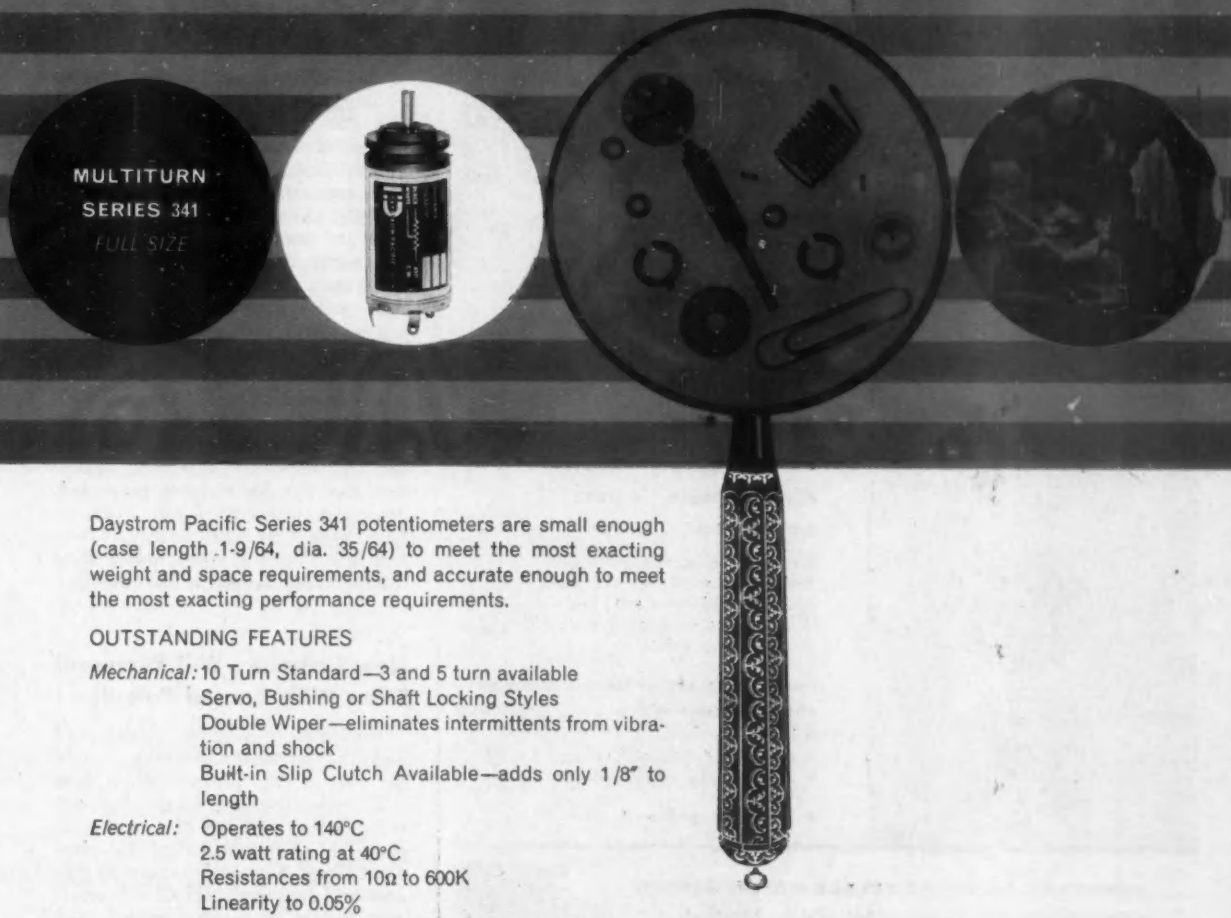
Leading the manufacturing group with over $200 million planned for this year each are makers of transportation equipment (mostly autos), machinery builders (including electrical), and chemical firms. Machinery makers have by far the largest present plans for 1960—over $250 million. Transportation companies reporting will slip to $187 million in 1960 and chemical operators to $175 million. Companies in the "other metalworking" category (which includes instruments and controls along with fabricated metals) have planned for this year a 55 percent increase to $33.3 million over 1958's $21.5 million. Spending by participating companies in this field is expected to fall to $26.3 million next year.

• **Export sales lag**—As reported in last month's "Industry's Pulse", U.S. exports are growing slower than total sales. A total increase in exports of 1 percent is expected this year, 4 percent in 1960. Manufacturers last spring predicted total sales increases of 9 percent this year with an average increase of 6 percent annually during 1959-62. The other metalworking group companies (instruments, controls, and fabricated metals), however, expect an 11 percent increase in exports over 1959 to $759 million and 7 percent more in 1960 to $812 million. These figures, unlike those for foreign investment, have been expanded, using Commerce Dept. data, to include all companies.

Much faster growth is expected in sales by foreign subsidiaries. The average increase of all manufacturing companies in the survey is 7 percent this year and another 9 percent in 1960. In only one industry group—other metalworking—are export sales expected to increase faster this year than sales of foreign subsidiaries. Here a 3 percent increase in subsidiaries' sales is forecast for this year and 9 percent more in 1960.

CIRCLE 37 ON READER-SERVICE CARD →

SETTING THE PACE IN POT DESIGN



Daystrom Pacific Series 341 potentiometers are small enough (case length .1-9/64, dia. 35/64) to meet the most exacting weight and space requirements, and accurate enough to meet the most exacting performance requirements.

OUTSTANDING FEATURES

Mechanical: 10 Turn Standard—3 and 5 turn available
Servo, Bushing or Shaft Locking Styles
Double Wiper—eliminates intermittents from vibration and shock
Built-in Slip Clutch Available—adds only 1/8" to length

Electrical: Operates to 140°C
2.5 watt rating at 40°C
Resistances from 10Ω to 600K
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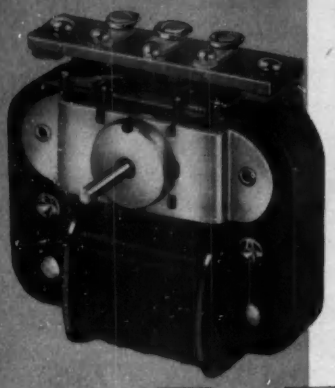
a-c small motors

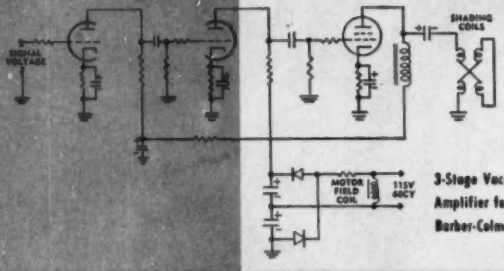
high quality... at low cost



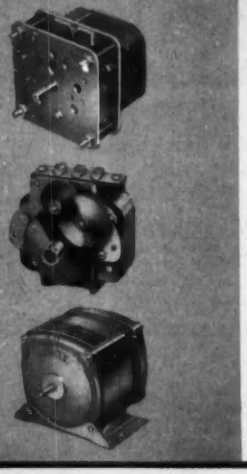
high torque, fast reversing motors

for servo-mechanisms, remote switching and positioning devices, recording instruments, and voltage regulators

Barber-Colman shaded pole reversible motors are adaptable to a variety of control circuits and power requirements up to 1/25 hp. They meet the specifications of many applications requiring a compact, powerful motor.



3-Stage Vacuum Tube Amplifier for Controlling Barber-Colman Reversible Motors



geared

double plate—open
single plate—open
enclosed

Barber-Colman shaded pole motors are available with both enclosed and open gear trains. Wide choice of models with wide range of gear ratios.

"plus" features of Barber-Colman shaded pole motors

- low inertia rotors
- porous bronze or ball bearings
- hardened and ground stainless steel shafts
- long-life rugged construction

FREE CATALOG HELPS SELECT MOTOR NEEDED

Get the helpful condensed catalog of Barber-Colman shaded pole small motors Contains complete descriptions of above motors, shows typical specifications performance characteristics, control circuit diagrams. Write for your copy

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Small Motors • Automatic Controls • Industrial Instruments • Aircraft Controls
Electrical Components • Air Distribution Products • Overdoors and Operators
Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery

CIRCLE 38 ON READER-SERVICE CARD

WHAT'S NEW

IBM Datacenters To Sell 7070 Time By The Hour

IBM has made a departure from its traditional monthly leasing policy for data processing equipment in announcing its plan to establish 25 to 30 Datacenters in major cities, each housing a solid-state 7070 commercial data processing system. Customers will have to supply their own programmers and operators and will be able to buy as little as 15 computing hours a month for under $300 an hour.

The new centers will differ from IBM's Service Bureau Corp. which performs a total package operation from analyzing the problem, through programming and actual processing, to delivery of the results. At the Datacenters, the customer will get a key to the 7070 and run his own work as he would in his own facilities. IBM sees the new service as a way for businesses who cannot afford their own systems to automate and convert older accounting methods and achieve smooth conversion to full-time systems as business growth requires. Other expected users: companies with peak loads beyond the capacity of their own systems, customers preparing to install 7070's (for training of personnel, checking out applications, and perfecting programs), and IBM and independent service bureaus.

IBM will be responsible for maintenance and servicing of the computers and will offer their customary education facilities for training personnel. The first Datacenter will open in New York City next March, a second in Chicago in April, and a third the following month in Los Angeles.

New Company Will Represent Firms With Unused Patents

Hundreds of valuable patents and ideas that have been gathering dust in the files of U. S. corporations may now become available for development through the workings of a new company, the National Patent Development Corp. Seemingly unique in purpose and function, NPDC will represent companies owning patents and processes in finding other concerns willing to develop them. The patents and ideas which NPDC will aid its clients in selling or licensing are those which do not have a natural outlet within the corporations' normal operations, and as a result, have remained untouched. Working from the other tack, NPDC will also advise its clients

of data it has received on patents which will be applicable to their field.

The first client to be announced is S. C. Johnson & Son, Inc., makers of "Johnson's Wax". The contract Johnson has signed gives NPDC exclusive rights to arrange for buyers or licensees for about 30 patents and formulas. The company claims that many major corporations have reacted favorably to its approach and that the patents they expect to make available are in the fields of industry, science, and medicine. A survey NPDC conducted indicated that patents lying unused represent several hundred million dollars in research.

Chairman of the board of directors of the new firm is Jess Larson, former Federal Works Administrator and Chief of the War Assets Administration. NPDC will have offices in New York City and Washington, D. C.

New Bailey Organization Will Buy Grown-up Firms

Missile Systems Corp. has been organized by F. M. Bailey, veteran manufacturer of missile and aircraft electronic equipment, in North Hollywood, Calif. Bailey, who has been president of American Microwave Corp., Electronic Wire and Cable Co., and Ling Systems, Inc., outlined that MSC will engineer, manufacture, and market components and electrical systems for the aircraft and missile industry. The company will serve primarily as a vehicle for the acquisition of companies whose growth has exceeded their production, financial, or sales capabilities.

MSC will provide administrative assistance, production and marketing experience, as well as funds for the development of its acquired businesses. Along with Bailey, who will be president and board chairman, will be W. M. Rogers as secretary-treasurer and Cameron G. Pierce and James J. Ling as directors.

The new company also announced its first acquisition: you guessed it—Ling Systems, Inc. Ling's activities —seemingly old stuff to the MSC people—will not substantially change; they have been in the manufacture of cable systems and microwave and telemetry equipment.

Gulton Industries Forms Data Analysis Unit

A new Gulton Industries, Inc. division will specialize in statistical and data analysis—extracting usable information from telemetered or signal data before transmission. In addition to

(Continued on page 290)

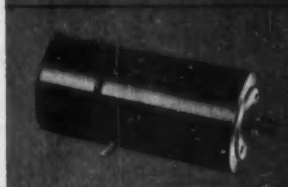
THE MARK OF QUALITY

BARBER COLMAN

VERSATILE, RELIABLE ELECTRICAL COMPONENTS FOR YOUR PRODUCTS

precision d-c motors

Small, high-quality d-c motors for industrial equipment and aircraft control applications. Output up to 1/10 hp . . . permanent magnet and split series types . . . various mountings and speeds. Offered with gearheads or blowers. Radio noise filters available.



a-c 400 cycle motors

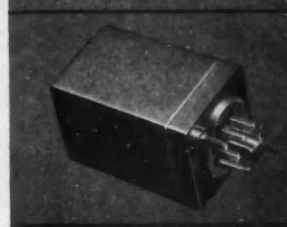
Precision missile and aircraft a-c motors designed to MIL-M-7969a. The capacitor type, four-pole motor features a balanced winding permitting reversal with an SPDT switch. A 400-cycle brake is available. Typical rating is .020 horsepower at 9700 rpm and 83 watts input, intermittent duty.

tach generators

For accurate speed indication and servo rate control applications. Supply up to 40 volts per 1,000 rpm within plus or minus 0.5% linearity. Standard temperature range is −65° to +200°F, but units have been made for −65° to +500°F ambient.

low-cost d-c motors

High-quality, compact governed d-c motor is available in speeds from 1200 to 6000 rpm. Voltages from 3 to 30 volts d-c. Suited for many battery-operated applications such as: drive mechanisms in photographic equipment, marine navigation equipment, portable dictating machines, signal-seeking radios, tape players, and portable instruments.



polarized d-c relays

Ultra-sensitive polarized d-c relays capable of operating on input powers *as low as 40* microwatts. Available with three types of adjustment: null-seeking . . . symmetrical magnetic-latching . . . or conventional form C snap-acting. Can also be supplied with integral transistor preamplifiers.

resonant relays

Characterized especially by low operating power and narrow band width. Coil impedance is high enough to be operated in the plate circuit of a vacuum tube without impedance matching devices. Can be supplied tuned to any frequency between 115 and 400 cps.

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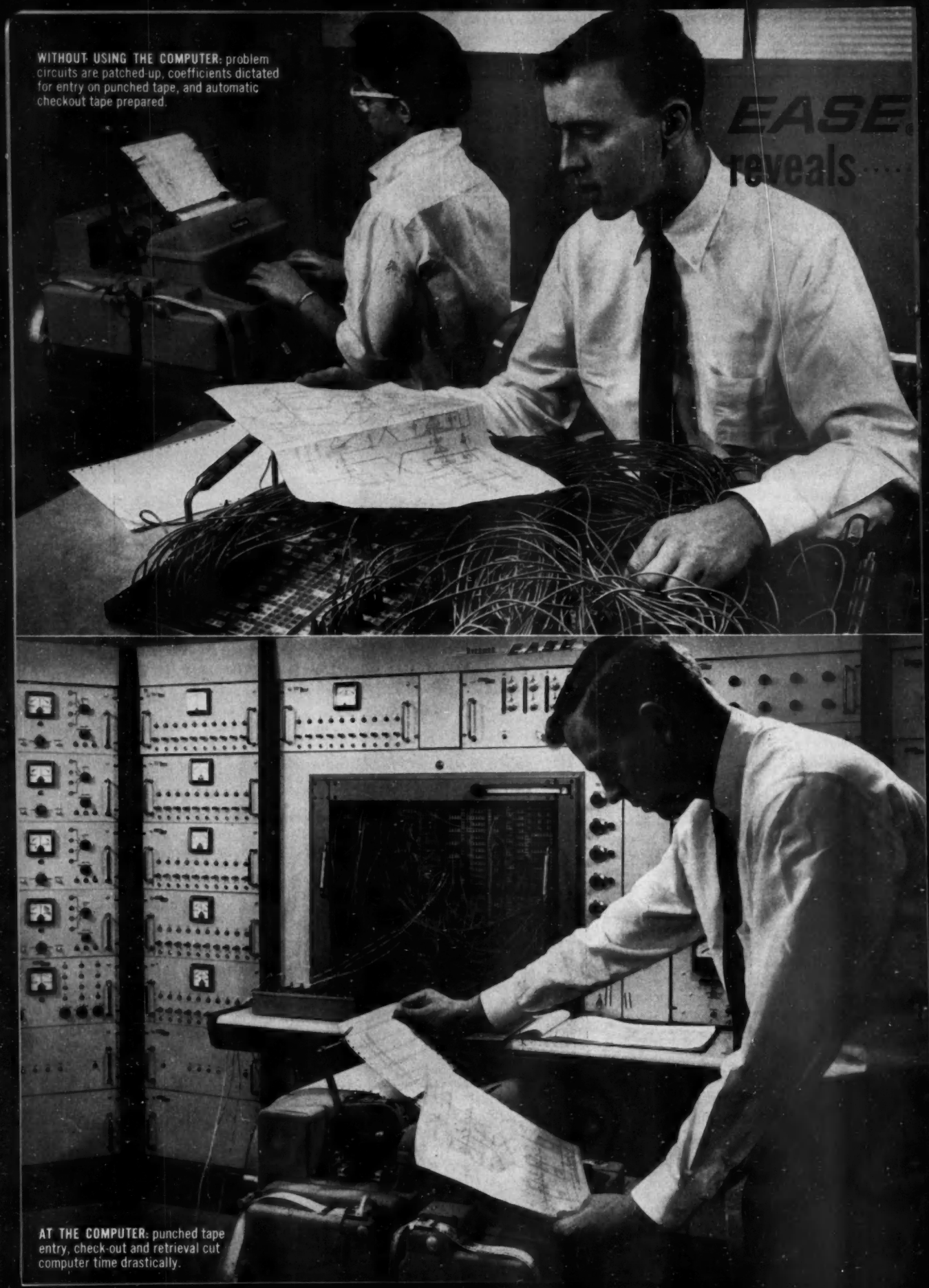
CIRCLE 39 ON READER-SERVICE CARD



WITHOUT USING THE COMPUTER: problem circuits are patched-up, coefficients dictated for entry on punched tape, and automatic checkout tape prepared.

AT THE COMPUTER: punched tape entry, check-out and retrieval cut computer time drastically.

.....HOW TO SOLVE MORE ANALOG PROBLEMS IN LESS TIME

How Much Time Does a Computer Spend Computing?

As analog computing problems become more complex, more time is spent setting up and checking the electrical analog, and less time actually generating solutions. When we consider that actual computation sometimes occupies less than 1% of total computer time, it becomes evident that any method of speeding up or eliminating set-up and check-out tasks offers immense rewards —either by expanding problem-handling capacity or reducing the size and cost of an adequate installation. This month we wish to acquaint you with some of the time-saving techniques which have become practical with the introduction of digital control units.

A Device for Reducing "Non-Computational" Time

The EASE digital control unit, nicknamed the "DO/IT" system, is more formally known as the "digital output/input translator." Because we know it best and because we believe it excels in general utility, we will talk about ways of using the DO/IT. A number of the techniques are applicable to other digital control systems.

In case you are unfamiliar with the DO/IT, it is a mechanism for entering and retrieving information via typewriter and punched tape. Its essentials are a Flexowriter coupled to the computer through a battery of telephone-type relays. The relays actuate a digital-to-analog converter which, in turn, drives a servo-set potentiometer system. The DO/IT is capable of entering coefficient pot settings, commanding the computer to assume any operational state, and reading out values at any or all points in the problem-solving circuit. Although designed for EASE computers, the DO/IT will operate with other analog equipment.

Keeping this in mind, let us point out some of the techniques that have proved to be enormous time-savers at our Los Angeles Computation Center.

Eliminate Pot Set Error

The trick is to screen out errors before approaching the computer. A punched tape and typewritten record of pot addresses and desired coefficients is prepared in advance on a Flexowriter. This is checked and errors are corrected before entry. How about errors in the servo setting? These are more unlikely, but to insure that they do not occur undetected, the DO/IT prints out the actual setting after each command and conscientiously prints the setting in *red* if it deviates more than 20mv from the command value.

Locate Errors Quickly

"Debugging" the computer (that is, checking the electrical analog to be sure it corresponds to the equations being solved) is often a lengthy and tedious procedure. Errors in mechanization and patching are easy to make and sometimes difficult to locate. The best procedure is to calculate the value of selected variables under one or two static conditions, then test the computer to see if correct voltages appear.

For example, EASE 1100 Series computers have an operating condition known as "Static Check." In this condition the problem-solving circuit is connected exactly as at the beginning of a computing run except that suitable voltages are substituted for the output of each integrator. Theoretical values under these conditions are calculated in advance from equations or from mechanization diagrams. The calculated values are entered on a punched tape together with instructions to compare these values with those existing in the computer. The DO/IT makes the comparison: if calculated and actual values agree, it prints nothing; if there is a discrepancy, it prints the difference. An operator, scanning the printed record, can immediately pinpoint errors in patching and mechanization – in addition to errors created by possible faulty components. As an added insurance against error, this test may be supplemented by a similar check under initial conditions and a check made after an arbitrary computing time under "hold" condition.

Because automatic scanning and printout makes it easy to check a problem set-up, operating personnel are inclined to make frequent tests. These tests often expose errors which would cost hours or days of computer time if undetected.

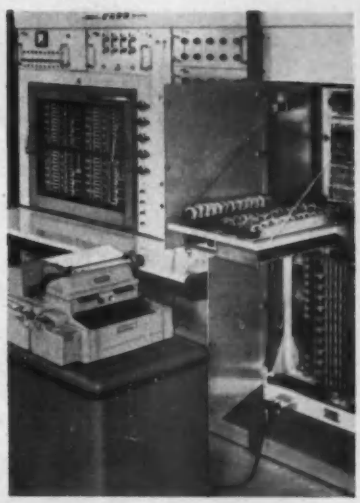
Program Survey Problems Automatically

In survey problems, equations remain essentially the same while a few parameters are changed from run to run. Solution of these problems can be speeded up by programing parameter changes on punched tape so that an entire series of computions will be run and recorded in rapid succession.

Run Two Problems "Simultaneously"

Problem handling capacity can be effectively doubled if two shifts of workers can use the same computer. Often this is impractical because one shift does not wish to destroy the set-up left by the previous crew, nor are they well enough acquainted with the problem to proceed with its solution. Punched tape entry and retrieval offer a way out of this dilemma. Each crew works on a separate problem. At the end of a shift, the people quitting work simply record all settings on punched tape and pull out the patchboard. Those coming on shift insert another patchboard and enter the previous day's setting via punched tape. In this way two projects can proceed simultaneously and without interference.

Write for further information on the DO/IT system, or better yet, see it in operation at our Los Angeles Computation Center, 305 Parkman Ave., Los Angeles 26. Kenneth Tuttle, Director.



The EASE digital control system, showing sturdy telephone-type relays which link flexowriter to digital-to-analog converter behind top panel.

Beckman® / ***EASE COMPUTERS***

Mfd. by Berkeley Division, Beckman Instruments, Inc. Richmond 3, California

CIRCLE 40 ON READER-SERVICE CARD

CIRCLE 41 ON READER-SERVICE CARD →

cppc for ANY

Servo Motors

SIZE 8 • 10 • 11

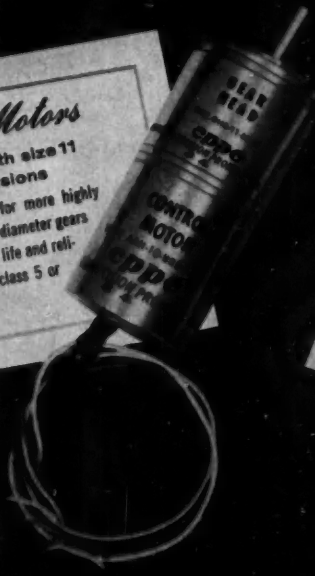
High torque for size. Will withstand 125°C. 26volt and 115 volt units available. Types for translator circuitry.

Linear Transformers

(Induction Potentiometers)

SIZE 8 • 10 • 11

These units feature low secondary impedances. Can be designed to work with wide range of load impedances. Infinite resolution. Linearity .5%. Wide variety. Can be temperature compensated.



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SIZE 10 • SIZE 10 with size 11 mounting dimensions

Available with off center shaft for more highly accurate meshing. Over size pitch diameter gears on smaller pinions for increased life and reliability. All bearings are ABEC class 5 or better.

D. C. Motors

SIZE 8

Smooth rotation at low speeds. Reversible. Speed linearly proportional to voltage. 28 or 14 volt input. Leads or terminals. Available with governor which maintains constant speed within ±1%.

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BuOrd • High Temp. (450°F)

Highest accuracy in production quantities (7′ max. error is typical); lowest nulls; lowest phase shifts; corrosion resistant construction, stainless steel or aluminum housings. Double ended shafts available. An extremely wide variety of synchros available as Transmitters, Receivers, Control Transformers, Differentials, Resolvers.

Precision Computing Resolvers

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Highest accuracy (functional error .03% to .1%). Excellent nulls, low phase shift. Units to resist 450°F. Resistive, feedback winding or thermistor compensation. Types for transistor circuitry. BuOrd shafts and Mk 4 Mod 0 brush block obtainable.

Motor Generators

SIZE 8 • 10

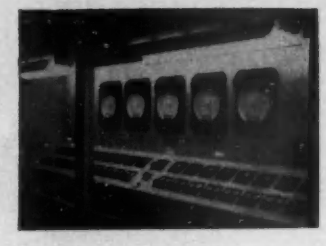
Minimum length and weight. Suitable for error rate damping in servo systems for high stability. Motor rate tachometers available. Types for transistor circuitry.

CO., INC.

These pages describe only partially our wide line of Precision Rotary Components. Write or telephone for CPPC's latest catalogue which gives complete electrical data and drawings. Special units are available to withstand severe vibration and shock, extremely high temperature, and radio-active environments.

Most units available for immediate delivery. Two plants (Clifton Heights, Pa. and Colorado Springs, Colo.) to serve you. Home Sales Office: 9014 West Chester Pike, Upper Darby, Pa., HIlltop 9-1200 (Suburban Philadelphia).

HAGAN NEWSLETTER
Behind the Panel



MIDWEST UTILITY GETS POWRMAG COMBUSTION CONTROL SYSTEM

Another Hagan electronic solid state combustion control system has been contracted for by a Midwest utility for a new unit to be completed in 1961. A single furnace, single drum boiler, it will operate at 2200 psi and 1010 FTT, and have a maximum continuous capacity of 2,310,000 lb/hr steam. The Hagan systems will control combustion, fuel flow, air flow, furnace draft and pulverizer temperature and suction. Hagan's PowrMag (magnetic amplifier) components will be used for most control functions and the entire system will be solid state. Main reasons for the selection of the Hagan systems were low maintenance requirements, high accuracy and stability, and Hagan's experience. (Item H-1)

HAGAN METER AUTOMATICALLY COMPUTES "BLAST UNITS" TO BLAST FURNACES

At a leading steel company, air delivered to blast furnaces is charged to the Blast Furnace Department in terms of "blast units." A blast unit is a measure of work required to compress the air by turbo-blowers and is equivalent to 1000 kwh of electrical energy, or approximately 3,415 Btu. Blast units are calculated in terms of standard cfm air flow corrected to 15 psi gage. A common method is to integrate total air flow from air flow charts by the use of a planimeter and correlate with the pressure chart to 15 psi gage by applying certain correction factors. This method is laborious and subject to error.

However, since the installation of the Hagan Blast Unit Meter at an Eastern plant of this steel company, blast units are obtained automatically and precisely. Pneumatic signals, proportional to standard cfm and blower discharge pressure, are transmitted to the blast unit meter. The computing mechanism within the meter integrates and records blast units. Operating personnel now have an accurate and continuous record, eliminating compromise figures and manual checking. (Item H-2)

HAGAN POWRLOG TEMPERATURE CONTROLS FOR GLASS FURNACES

Fed with raw materials of special quality for the production of glass cloth, these furnaces must maintain extremely accurate temperatures in each of three sections. Initial melting is performed in the melter, maintained at 2800F. From there the glass flows to the refiner (2200F), and then to the forehearth (2200F), where the bushings through which the fiber is drawn are located. Hagan PowrLog units, with a suppressed range of 1600F to 3000F, take indications from Type R thermocouples and maintain required temperatures within 5F. Eight furnaces are under Hagan control as well as eight recuperators. Trouble-free operation, minimum maintenance and quick delivery were some of the factors which influenced the choice of Hagan as the supplier for these systems. Where even closer control is required, it is interesting to note that Hagan PowrAmp temperature controllers, sensitive to thermocouple fluctuations of one-millionth of a volt, are used to control bushing temperatures. These are held within 0.25F. (Item H-3)

GAS MIXING STATION GOES ON FULL AUTOMATIC IN HALF A DAY

This system normally utilized natural gas, but since a propane-air mixture must be used as standby, a gas mixing station was installed. Key item in the station was a standard Hagan Dual Ring Balance meter equipped with ratio control. Flow to equipment in the gas line is measured by one ring. This signal is used to control the flow of propane, which is measured by the other ring. The established ratio, resulting in a 1200 Btu propane-air mixture, is maintained throughout the range of the meter. This type of proportioning control is exact and is useful in a great many applications, including chemical feed and combustion control. The meter was installed and placed on full automatic in half a day's time. When, at a later date, demand on the station changed, the Hagan meter was changed to the new, higher range by a simple and easily made field adjustment. (Item H-4)

HAGAN CHEMICALS & CONTROLS, INC.

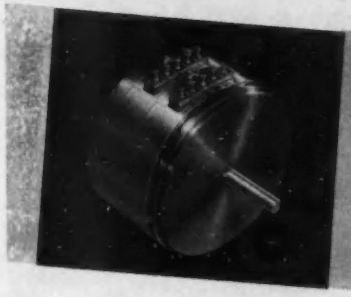
Hagan Building, Room 707, Pittsburgh 30, Pennsylvania
In Canada: Hagan Corporation (Canada) Limited, Toronto
European Division: Via Flumendosa No. 13, Milano, Italy

If you would like more information on any of the above items, check the appropriate box below.

☐ Item H-1 ☐ Item H-2 ☐ Item H-3 ☐ Item H-4

for *precise* control....

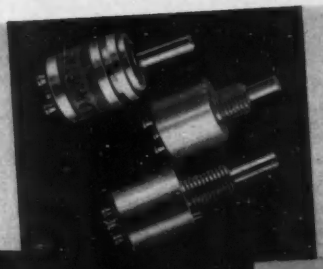
CLAROSTAT PRECISION POTENTIOMETERS



for stringent environmental conditions...

VARI/PHASE
series 54

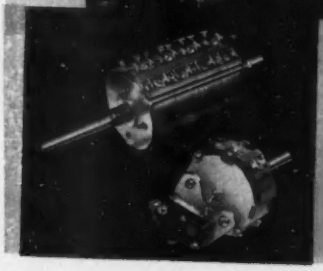
Windings phased to meet application. Available in four sizes from 2- to 10-watts. Resistance range up to 200K ohms, depending upon unit size. Overall diameters from ⅞" to 3". "Claroseal" construction available to meet environmental applications.



for space-saving...

½" POTENTIOMETER
series 57

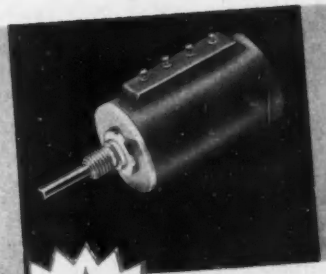
Provides more performance in less space. Combines special rotor with Hi-Load winding element for maximum stability and reliability. Nickel-silver body only ½" in dia. Features new Clarostat positive mechanical internal lead connections. Ranges to 40K ohms. Linearity, ± 2% standard; ± 1% special.



for versatility...

"42" POTENTIOMETER
series 42

Precision potentiometers rated at 3 watts. Available in resistance ranges up to 100K ohms, from 1 ohm. Continuous or limited rotation. High-dielectric phenolic case. Units ganged by means of threaded tie rods. Switches available for actuation at any shaft position.



for super accuracy in effect and read-out...

MULTI-TURN
series 55

Potentiometers in 3- to 6-watt ratings. Diameters from .875 to 2". Improved design permits 20% more winding length for same outside diameter, resulting in greater overall resistance and higher resolution. Taps available.

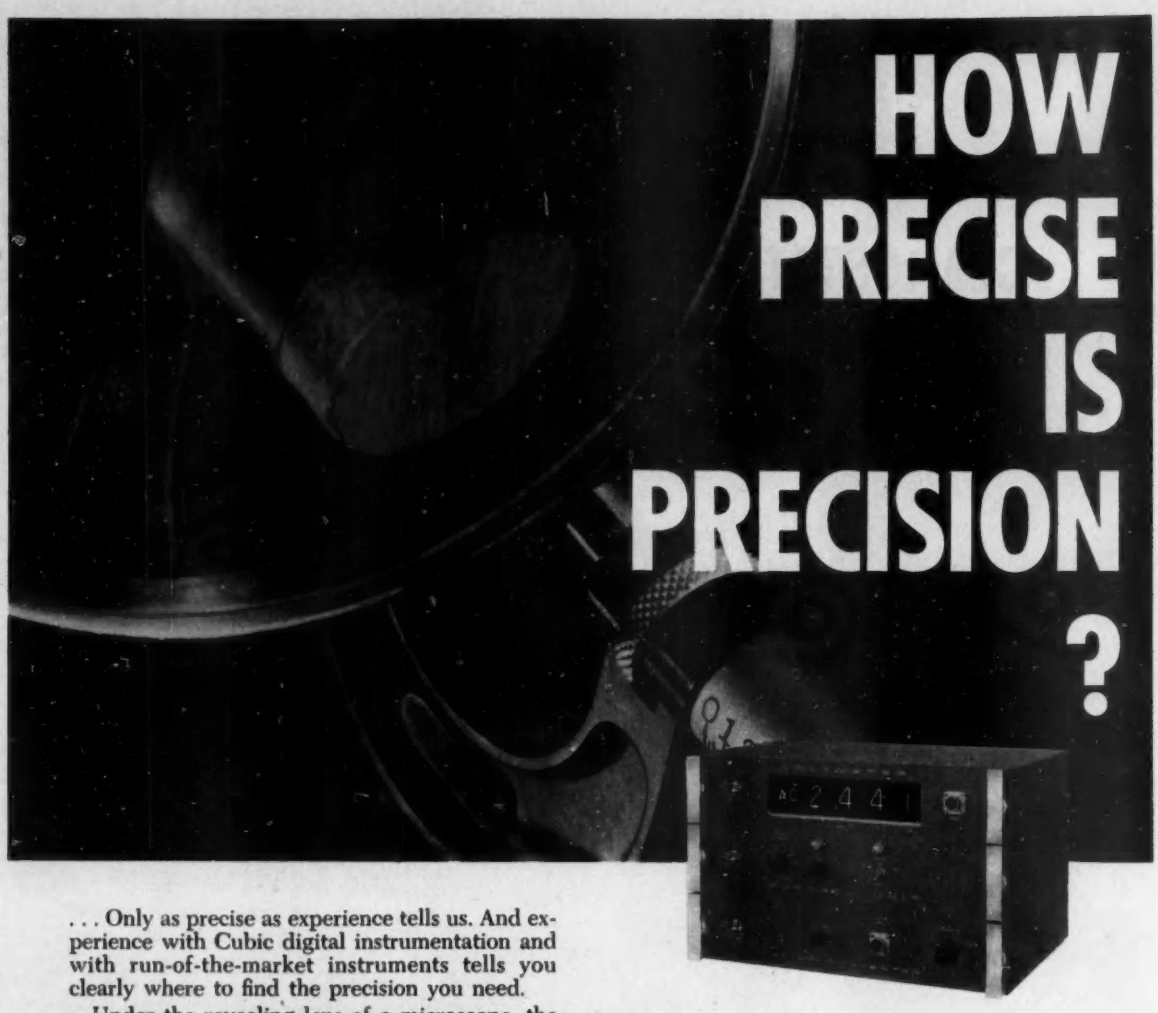
CLAROSTAT®

● **These items are available from your Industrial Distributor. Write us for technical data.**

CLAROSTAT MFG. CO., INC.

DOVER, NEW HAMPSHIRE, U.S.A.
In Canada: CANADIAN MARCONI CO., Ltd., Toronto 17, Ont.

CIRCLE 43 ON READER-SERVICE CARD



HOW PRECISE IS PRECISION ?

. . . Only as precise as experience tells us. And experience with Cubic digital instrumentation and with run-of-the-market instruments tells you clearly where to find the precision you need.

Under the revealing lens of a microscope, the micrometer we accept as a definitively precise instrument shows surface flaws that cause us to wonder. We know, however, that we CAN depend on its vernier scale. *So, too, can you depend on the Cubic line of high-performance, precision digital instruments* built with your requirements in mind – not bargain-basement instruments of minimum specifications, spasmodic performance and intermittent accuracy.

Cubic offers the precision and dependability of consistently superior digital instruments for laboratory, process control, minute measurement, automatic operation . . . for your every need in fine instrumentation.

Four and five-digit Cubic DC Voltmeters combined with the Control Unit provide instrumentation for bench-top use or for simple insertion into elaborate systems. The Cubic AC Converter expands a systems capability for rapid, accurate measurement of AC voltages, with automatic or manual ranging models available. Cubic's years ahead design also extends into its superior line of four and five-digit Ohmmeters . . . and systems capabilities are further expanded with Cubic Scanners, Printer Controls, Ratiometers and DC Pre-Amplifiers. Monitoring, control, check-out, inspection, calibration, research and development are among the many large and small-scale applications possible with Cubic digital systems . . . together with Cubic advantages such as accuracy, speed, clear readout, unit construction and simple routine maintenance.

The skill and experience responsible for the superiority of Cubic's Space Age electronic tracking systems are also important components of Cubic digital instruments . . . yours for an easier job – done faster, better and with greater assurance.

CUBIC CORPORATION

5575 Kearny Villa Road, San Diego 11, California

Electronic Engineering With a Dimension for the Future

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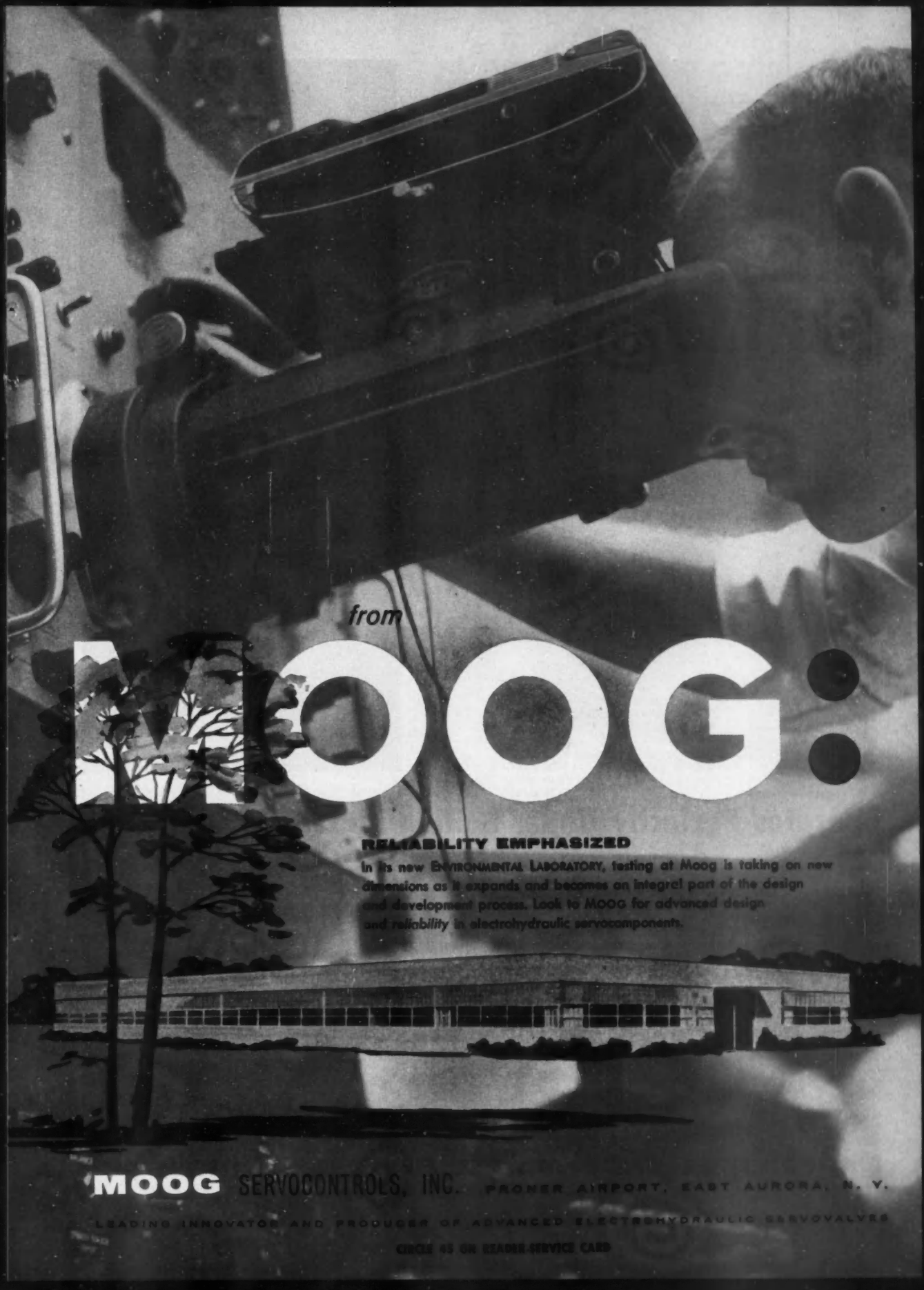
from
MOOG:
RELIABILITY EMPHASIZED
In its new ENVIRONMENTAL LABORATORY, testing at Moog is taking on new dimensions as it expands and becomes an integral part of the design and development process. Look to MOOG for advanced design and reliability in electrohydraulic servocomponents.
MOOG SERVOCONTROLS, INC. PRONER AIRPORT, EAST AURORA, N. Y.
LEADING INNOVATOR AND PRODUCER OF ADVANCED ELECTROHYDRAULIC SERVOVALVES
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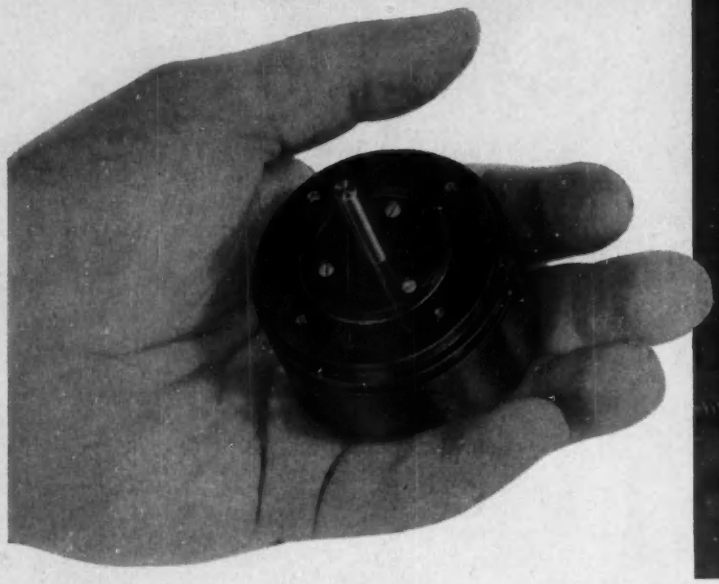
ASCOP
ALL-MAGNETIC SHAFT-POSITION DIGITAL ENCODER



Operates Perfectly Under Boiling Water For One Week

Just to make it hard for ourselves, we boiled one of our shaft encoders for a week with its cover off. It worked fine both during and after the test. We weren't surprised. ASCOP shaft encoders use no active circuitry, no optical or mechanical contacts in readout. The only contacting parts are the stainless steel bearings. The ASCOP encoder is made for tough environments in all combinations. If you like, you can drag it through the water, shoot it to any altitude, pressure cook it, or bury it in the Antarctic and expect it to behave perfectly. We've effectively done all these things in our own environmental laboratory and we haven't yet extended an EPD-8G encoder to its limit. Try it yourself. We can make immediate delivery from stock.

"See Encoder Demonstration in Booth 886 at ISA Show, Sept. 21-25"

Condensed Specifications

Resolution:	2[8]
Operating Temperature Range:	−80°C to +100°C
Size:	2¼" dia. x 1¼"
Weight:	8 oz.
Code:	Gray
Inertia:	70 gm-cm²
Shock:	100G for 6 ms, 4 directions for a total of 12
Vibration:	55 cps to 2000 cps for 40 min. at 15G, and 10 cps to 55 cps for 20 min. at 0.12" amplitude

Brochure, price and applications notes on request . . .

APPLIED SCIENCE CORPORATION OF PRINCETON

P. O. BOX 44 PRINCETON, NEW JERSEY

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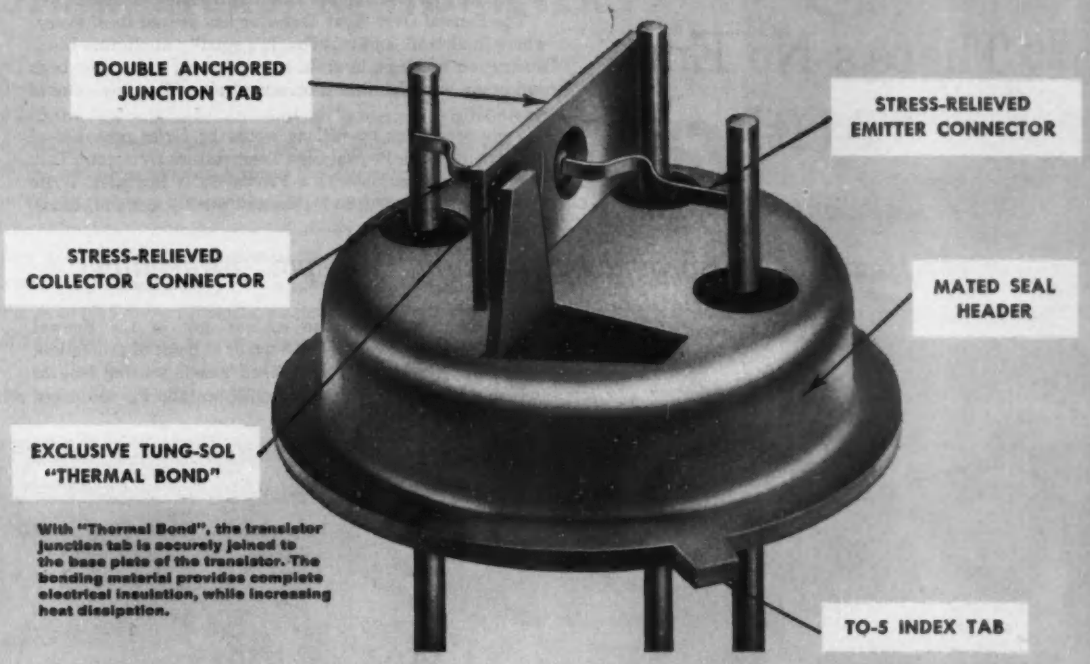
"THERMAL BOND"

EXCLUSIVE TUNG-SOL CONSTRUCTION

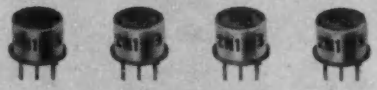
MEANS NEW STANDARDS OF TRANSISTOR PERFORMANCE IN COMPUTER APPLICATIONS



With "Thermal Bond", the transistor junction tab is securely joined to the base plate of the transistor. The bonding material provides complete electrical insulation, while increasing heat dissipation.

From Tung-Sol, originator of the Cold Weld Seal, comes a new design approach to greater mechanical reliability in computer switch transistors.

2N1313 (TS1000) is a PNP germanium alloy junction transistor which is designed for use in high current, high speed switching applications. This new transistor provides an ideal balance of the most wanted characteristics as revealed by survey of computer designers.



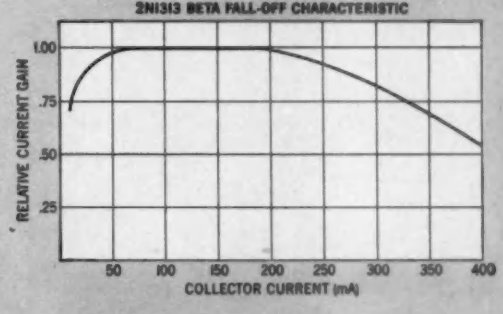
MAXIMUM RATINGS	
BV_{CBO}	—30V
BV_{EBO}	—20V
BV_{CEX} (V_{BE} = 0.1V)	—20V
BV_{CEO}	—12V
I_C (continuous)	400mA
I_C (peak)	1.0 A
T_j	—65°c to +85°c
P_C	175mW

TYPICAL CHARACTERISTICS (25°C)	
f_{ab}	12 Mc
C_{ob}	12 μμf
h_{FE} (I_B = 1mA)	60
h_{FE} (I_C = 400mA)	40
(t_r + t_d) (rise plus delay)	0.45 μsec
t_s (storage)	0.30 μsec
t_f (fall)	0.20 μsec
Thermal Resistance	0.350° C/mW
I_{CBO} @ —12V 25°C	2.5 μA
65°C	25 μA

1. Withstands 20,000 G centrifuge.
2. Exceeds all MIL environmental specs—shock—vibration—salt spray—centrifuge—moisture resistance, etc.
3. Excellent current gain linearity (low beta fall-off).
4. Thermal resistance derating is lowest for electrically insulated devices (.350° C/mW, typical).
3. Sensibly priced.

Immediate availability

Certainly, more information is available. Write: Tung-Sol Electric Inc., Newark 4, New Jersey



TUNG-SOL®

There's No End To It!

A Fenwal Continuous-Line Over-Heat Detector provides maximum "hot spot" protection

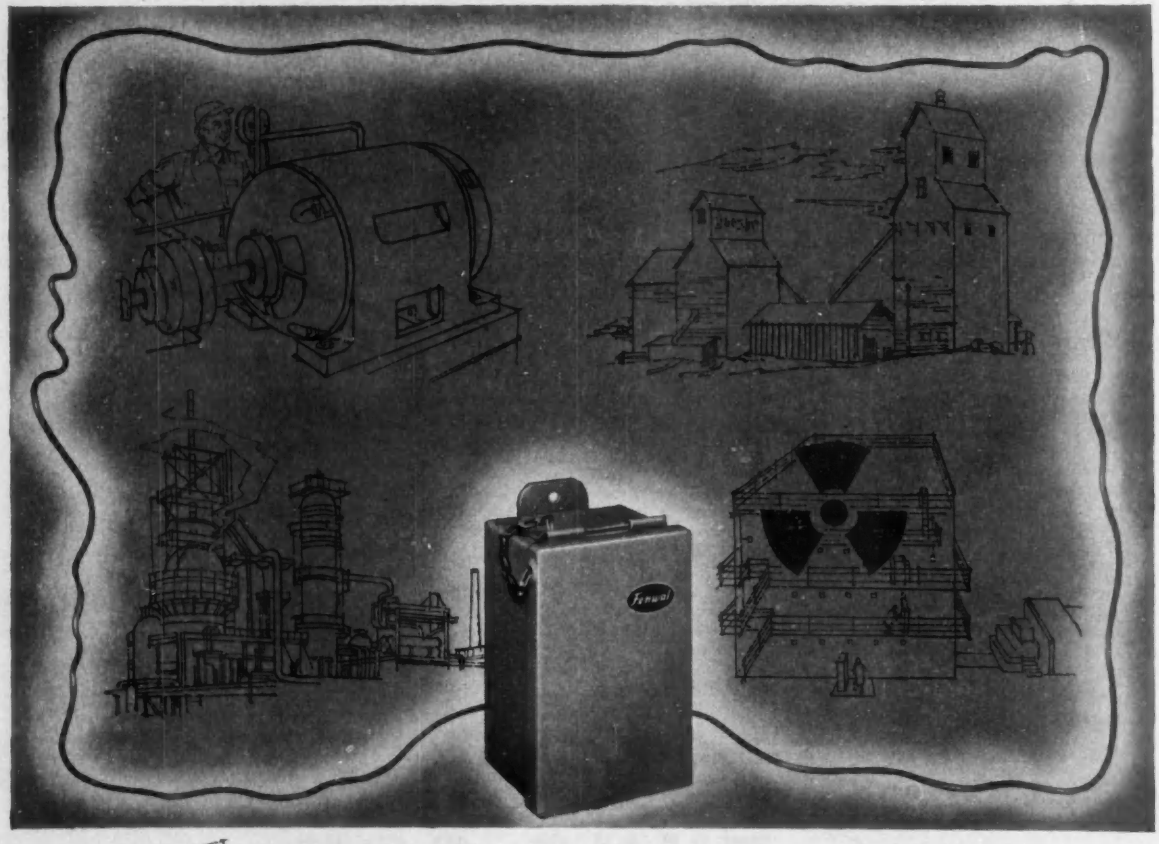
Hot as blazes, or just simmering, *any* undesirable temperature is quickly spotted by a Fenwal Over-Heat Detector. No individual sensors with resultant "dead spots." It's a discrete-sensing (non-averaging) system. Heat impinging at any point on sensing line triggers the alarm. *That's complete coverage!*

Line mounts easily — forms continuous loop back to compact control unit. Separate, connected lengths, set for different temperatures can operate independently. Rugged, solid-state design provides constant, fast-acting protection . . . requires no resetting. *A positive, trouble-free system!*

The Fenwal Over-Heat Detector has proved itself everywhere in aircraft and missiles. It's equally applicable in industry: on bearings, in grain storage areas, in catalyst beds and other petrochemical processing units. *There's no end to its uses!*

Your processing operations would be *better protected* at many points with Fenwal Line Temperature Detectors. Talk over your application with a Fenwal Sales Engineer. Write Fenwal Incorporated, 299 Pleasant Street, Ashland, Mass.

Alarm connects directly to control unit of the Fenwal Continuous-Line Over-Heat Detector at point of protection; or by simple wiring at centralized panel. Sensing lengths available for temperatures from 255° to 1200°F.



ANOTHER EXAMPLE OF HOW **Fenwal** CONTROLS TEMPERATURE . . . PRECISELY

DIGITAL VOLTMETERS OHMMETERS, RATIOMETERS

and Allied Products

Technological advance requires automatic high-accuracy measurements that only digital voltmeters can make. Customers in advanced fields find that NLS digital voltmeters last up to 5 and 10 times longer, a benefit from the producer who originated the digital voltmeter and who has the greatest research and development experience. Some applications are: missile checkout, computers, reliability testing, process monitoring, quality control, and general laboratory use. NLS features are unique because they were designed for application and not just for competition. Features of NLS meters include: *complete* transistorization, mercury relay digitizers rated at 3 billion readings, plug-in oil-immersed stepping switches, "no needless nines" digital logic for high speed and long life. Write today for complete data on AC-DC digital meters and accessories.

Prices and specifications subject to change without notice; prices (quoted f.o.b. Del Mar) slightly higher in Alaska, Hawaii, and outside U.S.A.

V-44 ALL-ELECTRONIC DIGITAL VOLTMETER — 500 readings per second . . . measures DC voltages from ±0.001 to ±999.9 volts . . . input impedance 10 megohms . . . completely automatic . . . output for data logging accessories.

M-24 VOLT-OHM-RATIOMETER — Measures DC voltages of ±.0001 to ±999.9 volts; resistances of .1 ohm to 1 megohm; DC voltage ratios to ±.9999 . . . transistorized completely automatic . . . connectors for data logging accessories . . . complete — $4950.

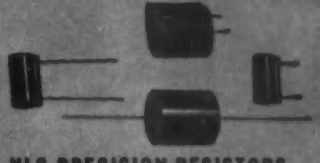
MODEL 125 AC TO DC CONVERTER — Adds AC voltage ranges to NLS DC digital voltmeters. Ranges, 9.999/99.99/999.9 volts. Frequency range, 10 cps to 10kc . . . Input impedance, 10 megs shunted by 20uuf . . . exceptional stability . . . complete — $1200.

V-35 TRANSISTORIZED VOLTMETER — Measures DC voltages from ±0.0001 to ±999.99 volts, DC voltage ratios to ±.99999 . . . completely automatic . . . plug-in stepping switches . . . 5-digit illuminated readout . . . complete — $3750 (4-digit V-34 also available — $3150).

NLS 481 LOW-COST INDUSTRIAL VOLTMETER — Measures and displays DC voltages of ±0.001 to ±999.9 volts . . . automatically selects and indicates range and polarity . . . 4-digit illuminated readout . . . one compact unit, 5¼-in. high . . . complete — $1285.

NLS 12 "OTRAC" — Semi-automatic oscillogram trace reader and computer . . . permits tabular recording in sequence of digital values of 10 or more traces . . . new optigraphic reading head . . . centralized controls . . . quick-change data handling system.

NLS 50 GO/NO-GO VOLTAGE COMPARATOR — Instantly gives go/no-go indication of voltage level within range of ±0.001 to ±999.9 volts . . . 50 milli-second operating time . . . limit settings to ±0.01% . . . transistorized for highest reliability . . . 3½-in. high.



NLS PRECISION RESISTORS — Vacuum encapsulated in special epoxy resin . . . extremely reliable wire-wound precision resistors of 1 ohm to 5 megohms . . . meet MIL-R-9444 specifications and MIL-R-93 saltwater immersion tests . . . operating temperature limits of −55° to +125° C.

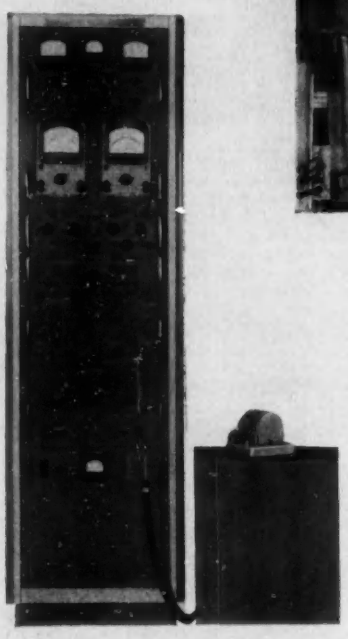
non-linear systems, inc.

Originators of the Digital Voltmeter
DEL MAR (San Diego), CALIFORNIA

NLS — The Digital Voltmeter That Works . . . And Works . . . And Works!

HIGHER ACCURACY and STABILITY in Specialized Test Equipment for MISSILE GUIDANCE and RADAR SYSTEMS

SPECIAL ANTENNA AND RADOME TEST EQUIPMENT
for automatic antenna boresighting, automatic pattern tracing, radome insertion loss measurements, measurements of boresight angular error and angular error slope resulting from radome non-uniformity.



INERTIAL COMPONENT TEST EQUIPMENT
for production checkout of integrating gyros including checks for magnetic suspension, floatation, gyro pick-off, torquing, etc. Gyro holding fixture is provided with heating coils and proportional heater control.

DUNN ENGINEERING custom designs and manufactures missile guidance, radar and specialized test check-out equipment. Shown above are two typical systems.

Other areas of competence include: analysis of missile guidance and radar system performance; electronic countermeasures; alignment and calibration of doppler navigation systems; application of radio interferometers to precise measurement of the arrival angle of electromagnetic radiation; closed-loop control systems; and special purpose computers for control and measurement purposes.

The Company has made significant contributions to the defense effort: TALOS — substantial improvements in missile guidance, POLARIS — specialized test and check-out equipments for gyros, SPARROW III — automatic test equipment for production testing of radome, ATLAS — programming of automatic tests for this ICBM.

Test equipment for advanced designs that approach the limits of the state of the art demands the ultimate in accuracy and stability. Dunn Engineering has successfully designed and manufactured test equipment that exceeds the most stringent performance requirements.

Capabilities Brochure will be supplied on request.

DUNN ENGINEERING ASSOCIATES, INC.

225 O'BRIEN HIGHWAY, CAMBRIDGE 41, MASSACHUSETTS

Telephone: UNiversity 4-6700

ADVANCED RESEARCH AND DEVELOPMENT IN ELECTRONICS

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Just Had a Sneak Preview of BS&B's Exhibit For The ISA Show!

LOOK FOR THE...

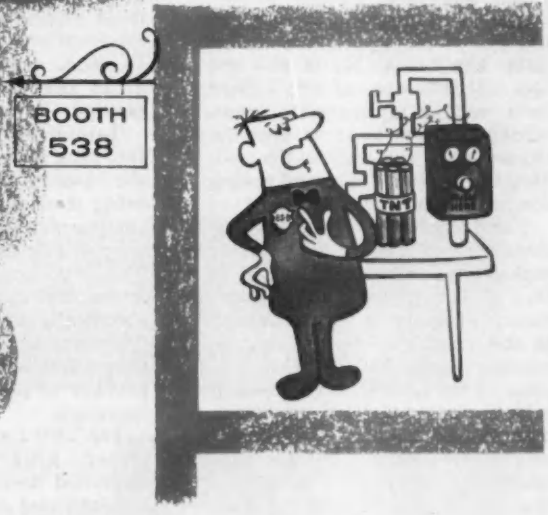
NEW! True Mass Flowmeter developed by BS&B and General Electric.

NEW! Giant 12 Inch Super 70 Control Valve

NEW! Complete Line of Angle Valves

NEW! Safety Head Applications for rockets and missiles

Plus!!! Late innovations in Relays, Supply Gas Regulators, Level Controls.

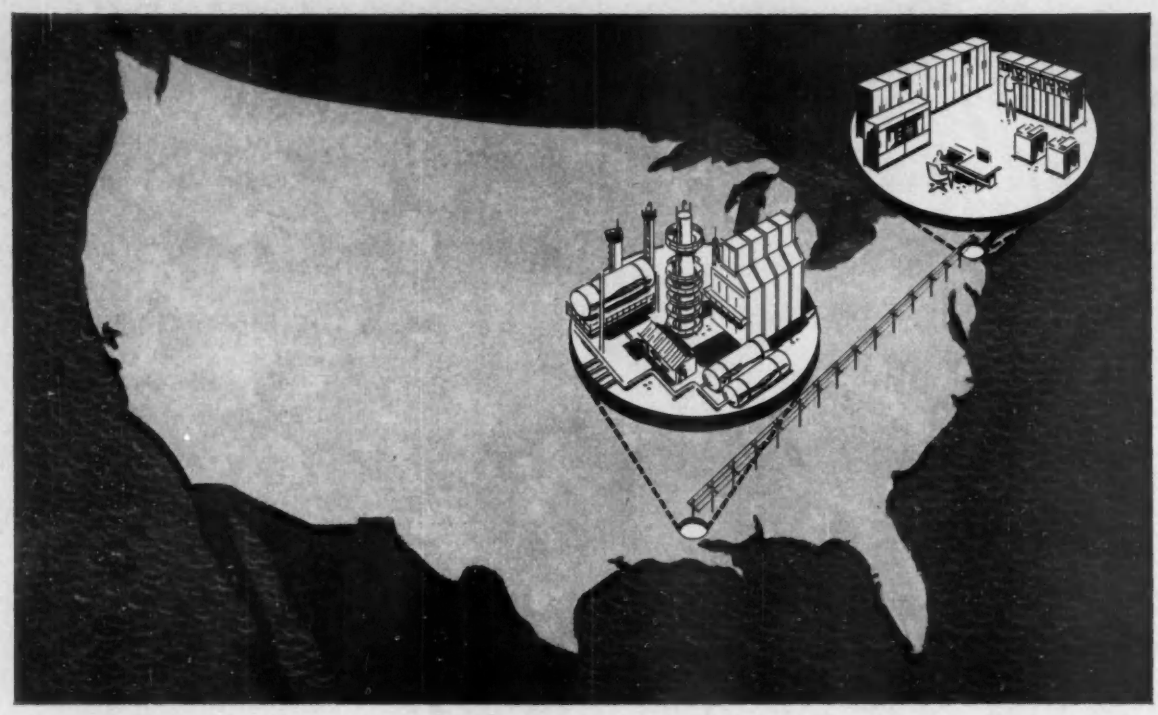


BLACK, SIVALLS & BRYSON, INC.

7500 East 12th Street Kansas City 26, Missouri

Better Process Controls For Industry

CIRCLE 51 ON READER-SERVICE CARD



Now...in addition to on-line computer systems

Operating and test data reduction via telephone link utilizing any computer facility

The new Daystrom TPR Scanning System represents a revolutionary approach with vast implications where there are requirements for immediate or continuous computer analysis of plant operating or test data. The availability of this new tool will influence industry's plans in a number of important areas, which include process studies, experimental test work in the military and nuclear areas, and testing for performance guarantees.

For the first time, the TPR (tape programmed raw) data scanner makes it possible and practical to link a test or operational plant facility directly to any computer in the country for instant computation of data. This is made possible by the utilization of standard telephone communication services, and permits stationing of all engineering and computer programming personnel at the project site, where all phases of the work may be handled.

The importance of this development is brought into sharp focus by the almost non-existence of computer facilities at actual plant or test sites. The utilization of telephone circuits completely circumvents this problem since it makes little difference whether the computer facility to be used is located in an adjoining building, company headquarters or at a rental facility. Distance represents no problem other than nominal telephone service charges.

Telephone communication of this type is a practical reality in the business machine field and is being used every day by leading companies for inventory control, accounting and other purposes. The Daystrom TPR Data Scanner is the first system that has been specifically designed to handle the problems involved in gathering large amounts of analog data peculiar to plant and test facility operation.

The TPR Data Scanner's feature of tape programming provides unlimited flexibility. This permits unrestricted application of the equipment to various types of facilities even though they may be completely different in nature.

Typical of the unequalled performance specifications are 0.1% accuracy at the 99% confidence level, together with extremely high signal to noise ratio at scanning rates up to 40 variables per second. 100% solid state circuitry and full parity checking are incorporated. Input channels may be as few as 100 or as many as 6000.

For further information, write or telephone Daystrom Systems, Dept. A-120, Miramar Road, La Jolla, Calif. GLencourt 4-0421.

Typical 2000 point system delivered to a major nuclear propulsion test facility.

DAYSTROM SYSTEMS
DIVISION OF DAYSTROM, INC.
Reliable computer control systems

New standards in high-volume production... by Bulova

Bulova ingenuity permits minimum inspection.

High-volume production techniques . . . perfected by Bulova to maintain their leading competitive position in consumer markets . . . assure repeatability and reliability of industrial and defense products.

To date, Bulova has manufactured more than 4,000,000 arming devices. Although reliability was crucial, only approved sampling techniques were required for inspection.

Experience in precision design and precision manufacture is the Bulova tradition, the Bulova capability. It has been for over 80 years. For more information write —

Industrial & Defense Sales, Bulova, 62-10 Woodside Ave., Woodside 77, N.Y.

BULOVA

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CIRCLE 54 ON READER-SERVICE CARD ▶

58 FACTS PROVE THE MC-5800 OBSOLETES EVERY OTHER ANALOG COMPUTER MADE

solves problems faster, more accurately, and at less cost!

The MC-5800 provides FASTER answers

1. Selection of real-time, expanded-time or high-speed compressed-time without reprogramming.

2. Real-time precision @ speeds to 60 solutions/sec.

3. Dynamic memory with time-base accuracy of ±10 μsec provides automatic parameter searching by iteration—an exclusive capability.

4. It programs 134 amplifiers, 30 electronic multipliers, 18 diode function generators, 2 time-delay generators, 8 relay amplifiers, and 6 servos from one 2128-hole patchboard.

5. Unique automatic problem check checks problem-board patching in seconds and can record errors.

6. Exclusive electronic generators of the function of two-or-more variables may be programmed at patchboard in same time required for setup of single-variable generators.

7. Complete control of all amplifiers, multipliers, dividers, and non-linear equipment at patchboard.

8. Quick overload recovery in less than 1 sec.

9. It is the only computer offering card-programmed diode function generators.

The MC-5800 performs MORE ACCURATELY

10. Amplifiers provide lowest noise level output—less than one millivolt at unity gain.

11. Greatest distortion-free amplifier output—30 mils at ± 120 V—only 12 mils quiescent drain.

12. Lowest amplifier grid-current $< 10^{-9}$ ampere.

13. Stable amplifier operation over the entire feedback range from zero to infinity.

14. Drift < 50 μv in 8 hours in summing mode.

15. Amplifier frequency response—flat to 10,000 cps and only 3 db down at 28 kc.

16. Only diode function generators utilizing resistors, potentiometers, and diodes of equal quality to those in computing networks.

17. Only diode function generators with individual hi-lo gain positions for *each* segment.

18. Lowest function generator drift < 5 mv/8 hrs.

19. Highest servo multiplier accuracy, ±0.008%.

20. Only fully shielded patch *bay* and patchboard.

21. All contacts in patching system gold-plated.

22. Highest performance electronic multiplier—flat to 10,000 cps and only 3 db down at 20 kc.

23. Only servo multipliers and resolvers with zero backlash gearing—maximum one part in 36,000.

24. DC tachometer feedback on all servos.

25. Dynamic servo error—less than 50 mv at one cps.

26. Lowest step-function overshoot—less than 1%.

27. EVERY SPECIFICATION IS GUARANTEED TO BE TRUE PERFORMANCE STANDARD—IN SUSTAINED OPERATION.

28. Highest sin-cos resolver accuracy ±0.03% peak-to-peak.

29. Power supplies eliminated from console—lowest, most stable operating temperatures—rise < 3°C.

30. Passive networks stabilized at < 1°C above room ambient—no oven required.

31. Servo-set pots can be set to 2 parts in 10,000.

32. Accuracy of computing networks at least 0.01%.

33. Lowest computer cross-talk—rejection greater than 2,000 to 1.

The MC-5800 can be operated at LESS COST

34. Greatest available problem capacity per dollar—by 20%.

35. Least cost for future expansion.

36. Output tube filaments operate with DC bias for maximum life.

37. Centralized overload indication for quicker trouble-shooting.

38. Only computer with hermetically sealed transformers.

39. Choppers employ double-contacts in parallel for maximum life.

40. Plug-in relays and step switches throughout for least down time.

41. Plug-in dynamic components ease maintenance.

42. Quickest trouble-shooting by automatic problem check.

43. Costliest and best patching system for lowest programming cost thru maximum reliability of patchcord connections.

44. Choppers de-energized when computer in standby for max. life.

45. Separate power-supply venting minimizes room heat load.

46. Exclusive equipment-door packaging for free access and quick maintenance *without* shutdown.

47. Insulated patchboard prevents costly shorting accidents.

48. Sealed servo gear boxes for maximum reliability.

49. Fully transistorized ADRAC system with plug-in logic modules.

50. Available on lease basis as well as for purchase.

The MC-5800 can SOLVE MORE OF YOUR PROBLEMS

51. Exclusive dynamic memory makes automatic iterative solution of statistical or optimization problems a reality.

52. Dynamic memory + high-speed quick-reset rep-op provide practical approach to solution of simultaneous partial differential equations.

53. Exclusive bi-variable function generators can also be used as amplifiers, multipliers, or generators of single-variable functions.

54. More computer capacity per dollar means more solutions.

55. Solution of problems with up to 15 amplifiers in closed loops.

56. Starting with as few as ten amplifiers, at a cost of little more than the cheapest available computer, you can build to a complete computing center of unsurpassed performance.

57. Add-on capacity up to 134 amplifiers, 30 electronic multipliers, 18 diode function generators, 2 time-delay generators, 8 relays with amplifiers, 4 bi-variable function generators, 6 servos, 8 function switches—all field-expandable without mechanical rework or rewiring.

58. Add-on features include automatic problem check, integrator rate test, high-speed repetitive operation, dynamic memory, expanded-time base, compressed-time base, servo-set potentiometers, and ADRAC (Automatic Digital Recording and Control) system—all field expandable without mechanical rework or rewiring.

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more time to think!

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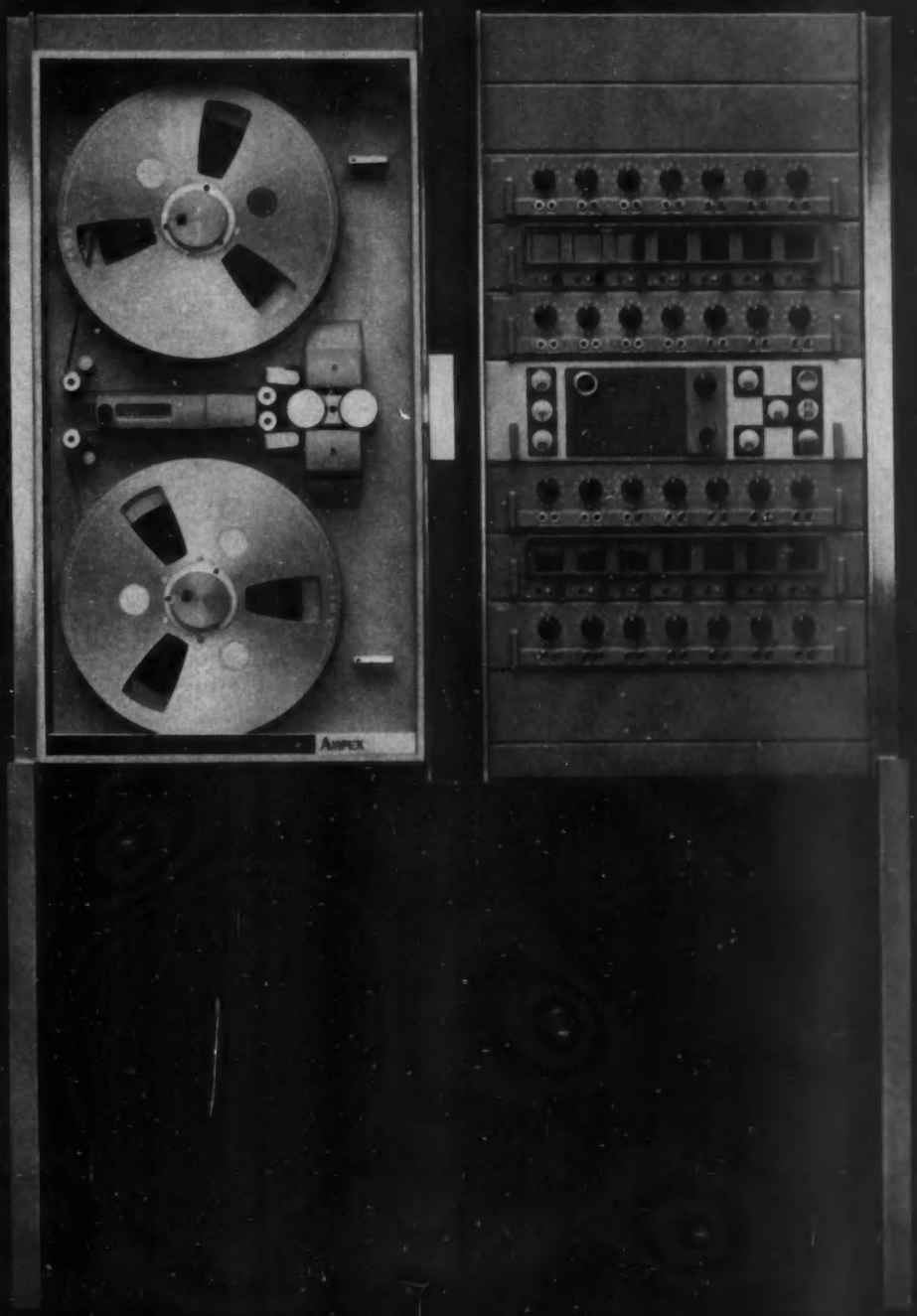
CIRCLE 55 ON READER-SERVICE CARD

NOW FROM AMPEX

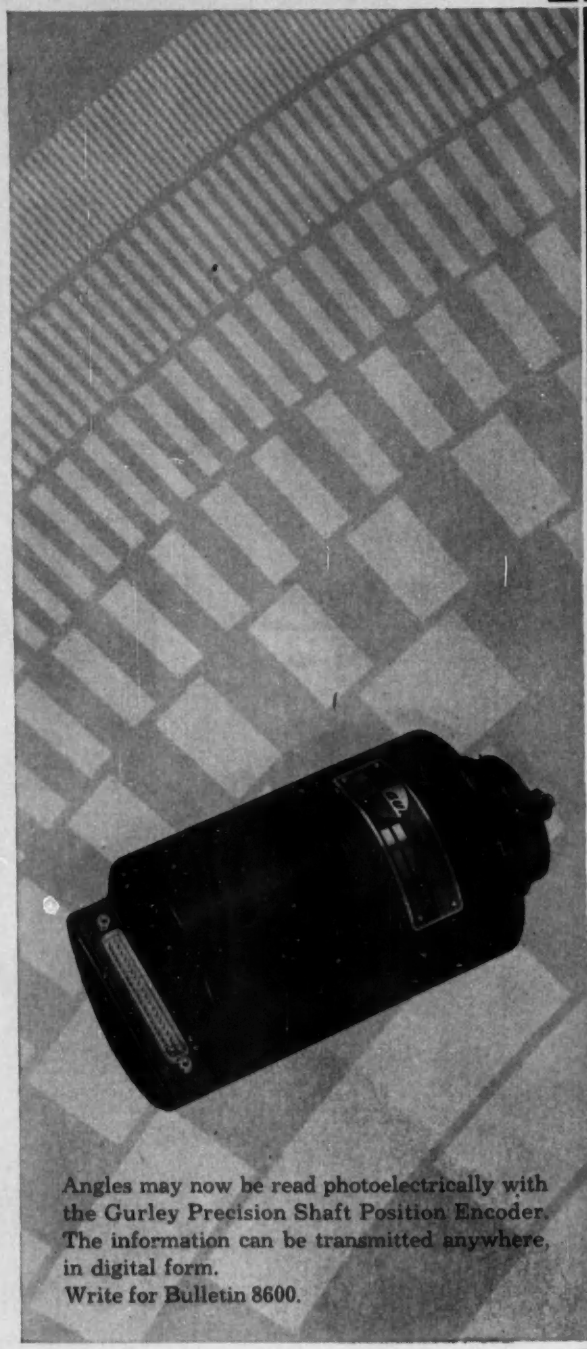
The world's most advanced scientific data recorder. More useful at a countdown than at a concerto, this third-generation machine—like its cousins and ancestors—brings you repeat performances at a fraction of the cost of re-staging the original, perhaps unique event—albeit satellite launching instead of symphony. Write Ampex Instrumentation, 934 Charter St., Redwood City, Calif., for a brochure on the distinguished new FR-600. It's solid-state . . . extremely reliable . . . extremely precise. You expect it from



Now there are 2 ways to read angles...

Photoelectrically with a Gurley Encoder

Optically with a Gurley UNISEC®



Angles may now be read photoelectrically with the Gurley Precision Shaft Position Encoder. The information can be transmitted anywhere, in digital form.
Write for Bulletin 8600.

You can read shaft positions to one second of arc—directly—with the Gurley UNISEC,® an Optical Coincidence Reading System, complete with a precision glass circle.
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CIRCLE 56 ON READER-SERVICE CARD

your electronic wire and cable problems end here

Fast moving electronic technology so often demands wire and cable construction to meet specific performance needs. As a "specialist in specials" Chester's engineering and production facilities are geared to meet both military and commercial requirements for plastic insulated wire and cable, while offering standard constructions for more general applications. The few types shown on this page are typical, high-quality Chester products, all of which may be varied to solve your electronic wire and cable problems.

SEND FOR THIS FREE CATALOG

The full story of Chester wires and cables for the electronic industry is in condensed catalog ELT-1.

COAXIAL CABLES

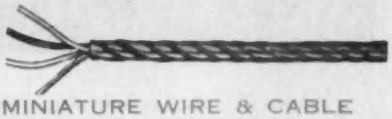
RG types in both standard and special designs; military or commercial versions. Meet all MIL specs. Miniature designs, too.

MILITARY HOOK-UP WIRES

A complete line for all military and commercial needs. Includes the new "Thrif-T-Bond"® bonded, tinned wire. Nylon, Teflon, braided jackets. Color-coded.

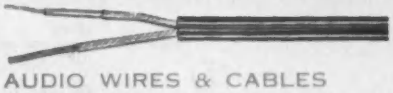
MULTI-CONDUCTOR CABLES

For computers and related equipment. Any number of color-coded conductors grouped to your requirements and sheathed.



MINIATURE WIRE & CABLE

Single or multi-conductor types in #18 to #30 AWG sizes with thin wall Plasticote® jacket. For radio, TV, electronic equipment.



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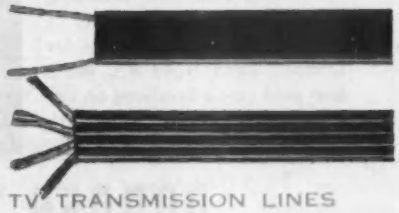
HI-V AND HI-F WIRES

High frequency test lead, high frequency lead wire and flame-retardant high voltage wire. For use on flyback transformers, accelerating anodes, etc.

APPARATUS WIRES

Wire sizes from #16 to #27 AWG, solid or stranded, Plasticote insulated. Range: —40°C to 90°C, 600 volts, AC.



TV TRANSMISSION LINES

Covering the broad field of TV, including lead-in wire, TV rotor cable, primary and secondary lead-in coaxial cables.

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CHESTER, NEW YORK
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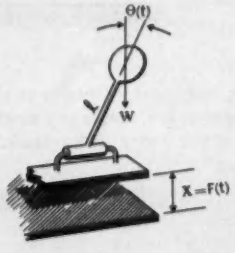
DONNER Desktop Computers

The small analog computer you see here accurately predicts system performance with extraordinary speed and simplicity.

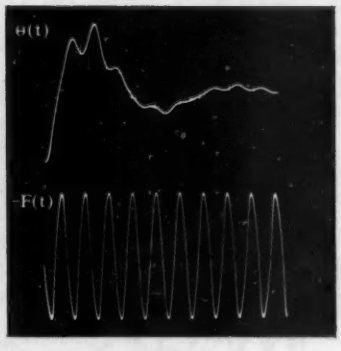
To illustrate, consider the problem of stabilizing the inverted pendulum below. Solving this problem requires a rigorous study of the stability of solutions to the Mathieu-Hill equation:



$$\frac{d^2\Theta}{dt^2} = \frac{g}{l} - A\,F(t)$$

In just 30 minutes, the computer solved the equations and established definite parameters. An expert mathematician who tackled the same problem at the same time was still working on his second page of calculations! After half a day's work, he had proved only that stability could be achieved—not that it was feasible for this particular pendulum.

The basic computer used in this problem, including two multipliers, costs less than $4,000. It can be readily expanded, initially or as your needs grow. Other Donner computers are available for your particular requirements.



By selecting the proper pivot excitation, A=F(t), the pendulum can be stabilized. The graph shows the time variations in displacement, Θ (t) as a function of pivot displacement F(t)=A sin ωt.

For a closer look at methods of studying non-linear systems with the analog computer, including a clear step-by-step analysis of the inverted pendulum, write for Donner Tech Note #2. We'll also send you a brochure on the Model 3400 computer. Please address Dept. 089.

DONNER SCIENTIFIC COMPANY

CONCORD, CALIFORNIA

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17-B

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NOW... *high performance magnetic amplifiers* at LOW COST!

New 1290 Series VICKERS *Super Power Magnetic Amplifier ...price is as little as one-half that of units previously available*

18 STANDARD UNITS—515 VA TO 32.5 KVA OUTPUT POWER

REACTOR BULLETIN NUMBER	A-C SUPPLY VOLTS	A-C SUPPLY PH	[1] DC CONTROL A-T	C_t	[2] CONTROL FACTOR	[3] D-C OUTPUT RATINGS V-A	VOLTS	AMPS	LOAD RES. (OHMS)	[3] 3-CYCLE CONTROL WATTS	RECTIFIERS SATURATING QTY	SATURATING CODE NO.	COMPLEMENTARY QTY	COMPLEMENTARY CODE NO.	[3, 4, 5] A-C OUTPUT RATINGS V-A	VOLTS	AMPS	LOAD RES. (OHMS)
1296-515	120	1	15	.016	0.73	515	77	6.7	11.5	1.5	1	VM2GVW1JA	2	VM3GVW1JA	825	98	8.4	11.7
1296-800	120	1	19	.013	0.95	800	77	10.4	7.4	1.9	1	VM2HVN1JA	2	VM3HVN1JA	1280	99	13.0	7.6
1296-1360	120	1	15	.037	1.70	1365	78	17.5	4.4	3.3	1	VM2NVN1JA	2	VM3NVN1JA	2210	100	22.1	4.5
1296-1680	120	1	17	.053	1.90	1680	78	21.6	3.6	3.8	1	VM2HVW1JA	2	VM3HVW1JA	2710	100	27.1	3.7
1296-2510	240	1	19	.029	2.1	2510	157	16.0	9.8	4.2	1	VM4NVN1JA	2	VM6NVN1JA	4060	201	20.2	10.0
1296-3160	240	1	19	.042	3.1	3160	158	20.0	7.9	6.2	1	VM4NVN1JA	2	VM6NVN1JA	5100	202	25.2	8.0
1296-4350	240	1	24	.033	3.8	4350	159	27.4	5.8	7.5	1	VM4JVW2JA	4†	VM6JVW1JA	6940	203	34.2	5.9
1296-6120	240	1	25	.050	6.3	6120	160	38.3	4.2	12.5	2	VM4NVN2JA	4†	VM6NVN1JA	9800	204	48.0	4.3
1296-7840	240	1	30	.043	7.4	7840	160	49.0	3.3	14.7	1	VM4KVW2JA	4†	VM6KVW1JA	12500	204	62.0	3.3
1296-2140	240	3	18	.013	0.85	2140	198	10.8	18.3	1.7	3	VD8GVW1JA						
1296-3320	240	3	22	.011	1.10	3320	200	16.6	12.1	2.2	3	VD8HVW1JA						
1296-5710	240	3	18	.033	2.20	5710	202	28.3	7.1	4.3	3	VD8NVN1JA						
1296-6830	240	3	20	.025	2.4	6830	203	33.6	6.0	4.7	3	VD8NVW1JA						
1296-10800	480	3	22	.025	2.5	10800	408	26.4	15.5	4.9	6	VH16NVN1JA						
1296-13300	480	3	22	.037	3.6	13300	410	32.4	12.7	7.1	6	VH16NVW1JA						
1296-18600	480	3	28	.029	4.6	18650	411	45.4	9.1	9.1	12†	VH16JVW1JA						
1296-25500	480	3	29	.041	7.0	25500	412	62.0	6.7	13.8	12†	VH16NVW1JA						
1296-32500	480	3	34	.035	8.2	32500	412	79.0	5.2	16.3	18‡	VH16NVW1JA						

1. *Ampere-turns required to control a typical unit.*
2. *Permits calculation of linear control power for any time constant.*
3. *All reactor ratings based on class "B" operation.*
4. *For full control (15:1 range).*

(Complete notes contained in Bulletin 1296-5.)

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■ GAPLESS CORES—permit minimum control ampere-turns; eliminate irregular performance introduced by air gaps.

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■ FOUR WEEK DELIVERY

Vickers, the pioneer in magnetic amplifier development, with more than 1,000,000 man-hours of direct experience in the design and application of magnetic amplifiers, now brings you a new line of higher power units . . . the "Super Power". 1290 Series. The new design of these tapewound, gapless core amplifiers coupled with superior production techniques provides Vickers 1290 Series Amplifiers with higher performance and operating efficiency . . . you get more output watts per dollar. Write today for complete details.

EPA 1290-2

Send for Bulletin 1296-5

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CIRCLE 59 ON READER-SERVICE CARD

LGP-30

ROYAL PRECISION

Here is the low-cost, desk-side electronic digital computer you need for general design and system optimization

Speeds optimum design of new products and equipment!

Operating from any convenient wall outlet, the compact, powerful LGP-30 will today furnish you with high-speed electronic computation wherever you need it . . . will eliminate tedious hand calculations . . . help you free up more creative time.

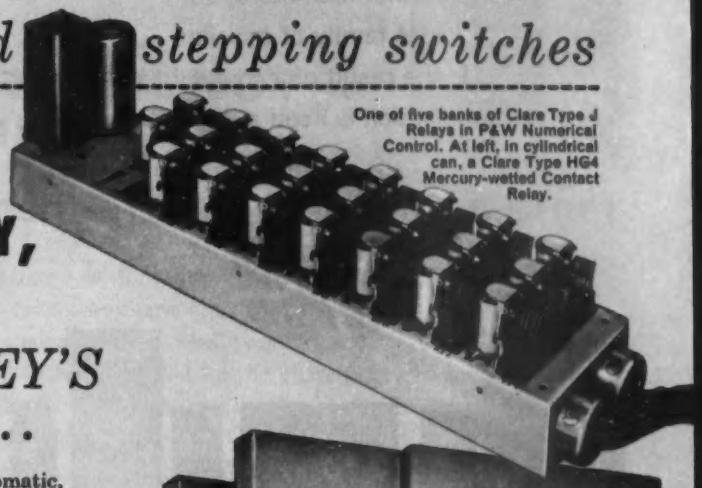
Combining large memory (4096 words) and stored-program operation, the LGP-30 gives you twice the capacity of any computer in its class, yet is by far the easiest to program in basic machine language. Simplified controls can be operated with only minimum computer experience. Answers are printed out directly—require no deciphering. Best of all, even with these many unique advantages, the LGP-30 is the lowest-priced complete computer you can buy. What's more, auxiliary high-speed input—output equipment is available for system expansion.

No expensive installation or air-conditioning required. Customer training is free. An extensive library of programs and sub-routines is available—as well as membership in an active users organization. Sales and service facilities are maintained coast-to-coast.

For further information and specifications, write Royal McBee Corporation, Data Processing Division, Port Chester, N. Y. In Canada: The McBee Company, Ltd., 179 Bartley Drive, Toronto 16.

ROYAL McBEE · *data processing division*

CLARE relays and stepping switches



One of five banks of Clare Type J Relays in P&W Numerical Control. At left, in cylindrical can, a Clare Type HG4 Mercury-wetted Contact Relay.

INSURE ACCURACY, INCREASE RELIABILITY, REDUCE SIZE *of*

PRATT & WHITNEY'S Numerical Control...

Pratt & Whitney's Numerical Control is a fully automatic, ultra-precise means of translating blueprint data into a series of machine positions. Applied to jig borers and other precision Pratt & Whitney machine tools, settings are made quickly, with high reliability to .0001" accuracy.

In operation, the Planning Engineer transfers to a Numerical Planning Chart all dimensional data from the blueprints which are necessary to determine the positions. Ordinary clerical help then punch these data into a tape. Machine positionings are then controlled by the tape or, when required, by a dial on the Operator's Console.

Here is what P&W's Mark H. Sluis has to say about the vital part played by Clare Relays and Stepping Switches:

"In the 4EA Numerically Controlled Jig Borer, punched-tape information is decoded by Clare Type J Relays and fed to a storage bank of 25 Clare Type 11 Stepping Switches. The selection of the proper storage switch is accomplished by a distributor—a Clare Type 26 Stepping Switch. In addition to storing the required command data for the slide positioning of this machine, logic circuitry comprises some 115 Clare Type J Relays.

"For ultra-reliability of the digit-selection circuitry, a dozen Clare Type HG4 four-pole Mercury-wetted Contact Relays are utilized.

"Through use of the Clare relays and stepping switches, our circuitry has increased in reliability, and a large contribution was made which enabled us to realize a 6:1 size reduction of the control system."

A Pratt & Whitney 4EA Numerically Controlled Jig Borer.

For complete information on Clare Relays and Stepping Switches contact C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Ltd., P. O. Box 134, Downsview, Ontario. Cable Address: CLARELAY

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ICBM family of missiles
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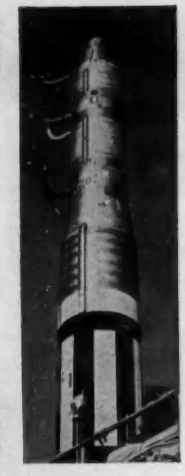

Titan, America's largest intercontinental ballistic missile, powerful enough to carry an H-bomb a distance of more than 5,500 miles, is a significant milestone in our national space program and for the science/government/industry team that conceived and produced it.

The entire plan for the Titan, Thor, and Atlas family of liquid propelled ballistic missiles was established less than five years ago. Experience gained in the Atlas and Thor programs made major contributions to the unprecedented success and progress of Titan. In addition, Titan again demonstrates the basic soundness, efficiency, and economy of the U.S. Air Force's management concept for ballistic missile and related space programs.

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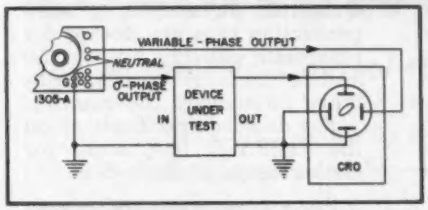
Space Technology Laboratories, Inc.

New LOW-FREQUENCY OSCILLATOR

for the direct measurement of GAIN and PHASE SHIFT

★ Frequency range: 0.01 to 1000 cycles per second ★ Built-in phase shifter: 0° to 360° ★ Direct reading in phase shift, *independent* of frequency . . . no charts or calculations necessary ★ Output amplitude stabilized ±½ db over entire frequency range ★ Three-phase output available . . . four-phase output from accessory adaptor ★ Especially useful for the phase-gain measurement of Servo Systems • Recorders • Medical Instruments • Networks • Passive Sonar Equipment • Low-Frequency Amplifiers • Geophysical Equipment • Electrical Analogs of Mechanical Systems • Two-, Three-, and Four-Phase Devices • Seismographic Devices.



Complex transfer characteristics of devices or systems are readily measured with the Type 1305-A Low-Frequency Oscillator. With the setup above, you need only adjust the Oscillator's continuously-adjustable phase shifter until the Lissajous ellipse on the oscilloscope is closed — the dial setting then gives phase shift directly. Gain is readily determined by calibrating the scope face with the aid of the Oscillator's panel meter, and then comparing vertical height of the oscilloscope pattern before and after the device under study is connected to the test setup.

Type 1305-A
Low-Frequency Oscillator

Frequency Range: 0.01 to 1000 cycles in 5 ranges. **Accuracy** ±3%

Three-Phase Output: 10-volts rms, open circuit, line-to-neutral, behind 600Ω in each phase. Output constant with frequency to ±5%. Phase voltages are equal to within ±2%.

Four-Phase Output: (using 4-phase adaptor) 5-volts rms, open circuit, line-to-neutral, behind 600Ω, phase voltages equal to within ±2%.

Variable Phase Output: 1-volt, rms, taken from a 50,000Ω output control. Accuracy of phase calibration is ±3°.

Waveform: Total harmonic content is less than 3% at all output attenuator settings and at all frequencies. Line-frequency hum in output is less than 10 mv.

Power Requirements: 105 to 125 (or 210 to 250) volts, 50 to 400 cycles.

Price: $940.

Write for Complete Information

GENERAL RADIO COMPANY

WEST CONCORD, MASSACHUSETTS

FIRST Broadcast Station Crystal Oscillator 1922

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"RESISTORIZED" NEON INDICATOR

...to MIL-L-6723 (ASG)

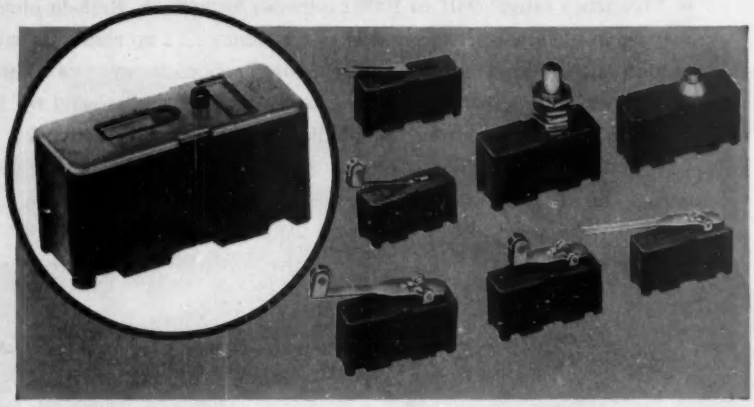
Keeping pace with the needs of miniaturized, ruggedized, transistorized equipment of minimized dimensions, Hetherington engineers have found space for an internal resistor in an indicator light that already is only 1 3/64" long. It's known as the Hetherington L15,000 Series and it's designed to MIL-L-6723 (ASG), Drawing MS25257. With the built-in resistor, the unit operates on 115 volts using MS25252-NE2D neon lamps.

If low-voltage incandescent lamps are preferred, 1 1/32" in length can be saved by specifying the still smaller L14,000 Series, designed to MS25256.

Both types have corrosion-resistant anodized aluminum sockets with integral mounting flanges, panel indexing tabs, and two solder-lug terminals. Lamps replace from the front by unscrewing the wide-visibility lenses. Center contacts are large silver-plated buttons, internally spring-loaded to resist vibration.

Complete specifications on both MIL-L-6723 (ASG) lights are shown in Data Sheet L-5a.

CIRCLE 63 ON READER-SERVICE CARD



New 20-AMP PRECISION SWITCHES

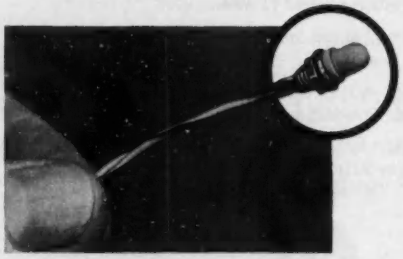
braced for toughest service!

Rigidly-braced phenolic cases of Hetherington Series S2A "HiPAC" Switches pave the way toward greater dependability and unsurpassed repeatability in critical control and positioning circuits. Molded-in safety limits prevent over-travel damage to the blade-type movable contacts. Extra bracing around mounting holes prevents case distortion from excessive mounting pressures. On the bottom, molded-in barriers and cup washers provide long creepage paths and positive separation between terminals and leads.

U. L. rated "HiPAC" Switches are presently available with any of eight actuators. All are interchangeable with other precision switches of equivalent ratings. Quantities for samples or small production runs are stocked for immediate delivery by over 50 leading electronic parts distributors throughout the country.

For detailed specifications on the "HiPAC" line, write for Hetherington Bulletin S-9.

CIRCLE 64 ON READER-SERVICE CARD



TINY LIGHT with a BRIGHT FUTURE

One of the smallest indicator lights ever developed, the Hetherington L10,000 Series measures only 15/64" in diameter by 35/64" long. It's equipped with wire leads and a threaded aluminum bushing that mounts in a clearance hole for a #10 screw. Secret of the L10,000's midget size is a fully moistureproof lamp/lens assembly that is molded to the mounting stem.

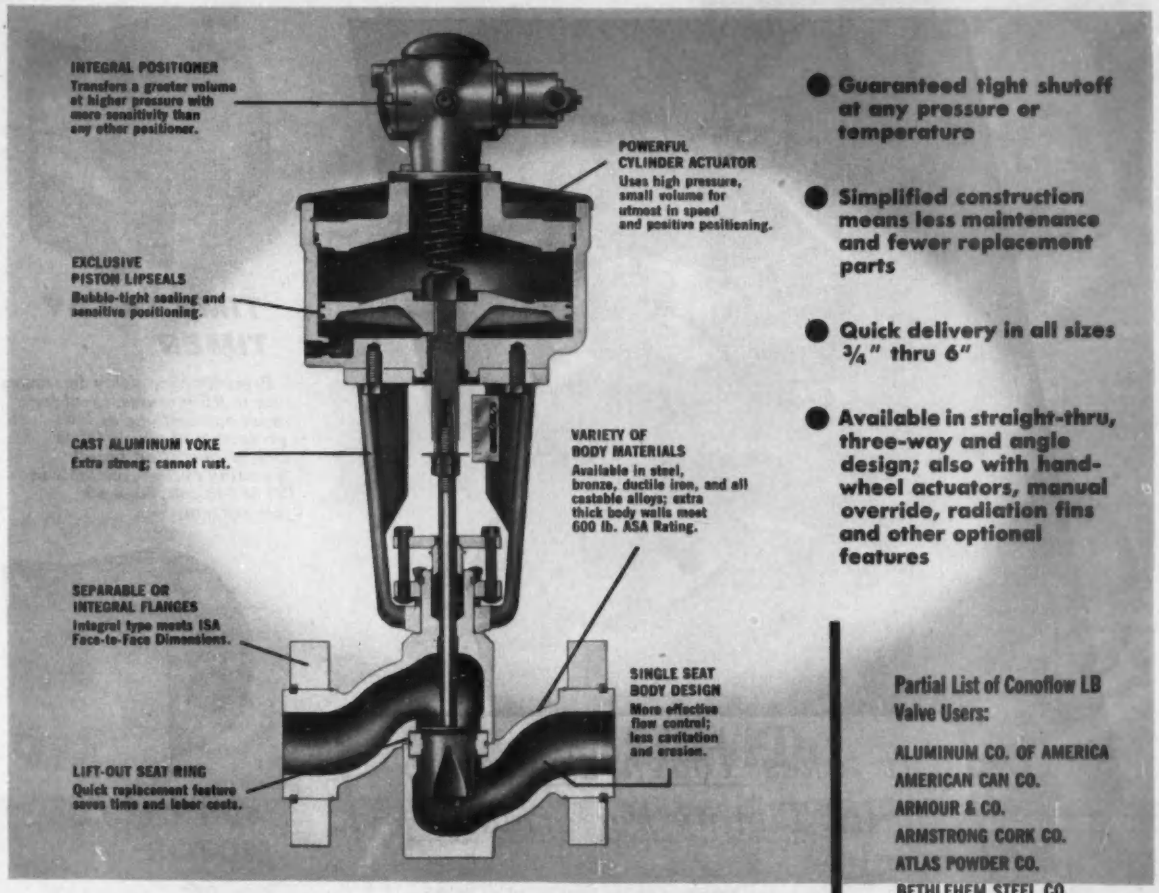
Designed for electronic equipment requiring components of minimum size and weight, the L10,000 gives bright, wide visibility for 60,000 hours at 5 volts dc. Many translucent colors are available.

Dimensions of the L10,000 are available on request.

CIRCLE 65 ON READER-SERVICE CARD

HETHERINGTON INC. DELMAR DRIVE, FOLCROFT, PA. • 139 Illinois St., El Segundo, Calif.

A Controls Company of America Subsidiary


INTEGRAL POSITIONER
Transfers a greater volume at higher pressure with more sensitivity than any other positioner.
POWERFUL CYLINDER ACTUATOR
Uses high pressure, small volume for utmost in speed and positive positioning.
EXCLUSIVE PISTON LIPSEALS
Bubble-tight sealing and sensitive positioning.
CAST ALUMINUM YOKE
Extra strong; cannot rust.
VARIETY OF BODY MATERIALS
Available in steel, bronze, ductile iron, and all castable alloys; extra thick body walls meet 600 lb. ASA Rating.
SEPARABLE OR INTEGRAL FLANGES
Integral type meets ISA Face-to-Face Dimensions.
SINGLE SEAT BODY DESIGN
More effective flow control; less cavitation and erosion.
LIFT-OUT SEAT RING
Quick replacement feature saves time and labor costs.

- **Guaranteed tight shutoff at any pressure or temperature**
- **Simplified construction means less maintenance and fewer replacement parts**
- **Quick delivery in all sizes ¾" thru 6"**
- **Available in straight-thru, three-way and angle design; also with hand-wheel actuators, manual override, radiation fins and other optional features**

USERS FROM COAST TO COAST SPECIFY

"CONOFLOW LB VALVES

for Automatic Control that's Headache-Proof"

When company after company switches to Conoflow LB control valves—and constantly reorder—there must be a reason. Leading manufacturers use Conoflow LB valves because they want headache-proof control—and they get it. Specify Conoflow LB valves for performance, economy and dependability—*complete* satisfaction. For additional information telephone your Conoflow representative (located in principal cities); or write to Conoflow Corporation, 2100 Arch Street, Philadelphia 3, Pa. for Bulletin LB-3.

Visit us in BOOTH 516 at the ISA SHOW

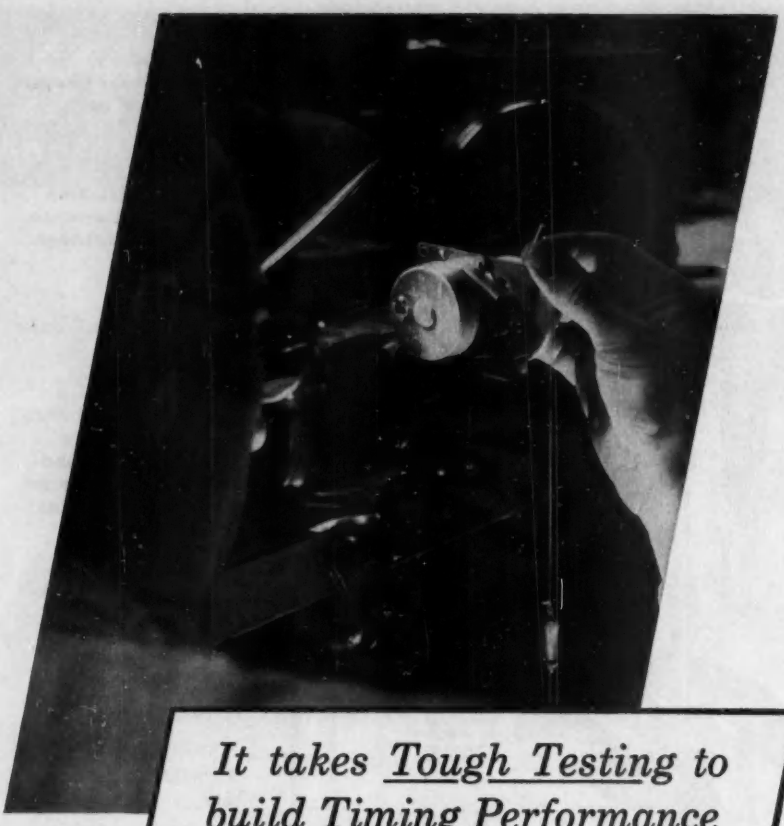
Partial List of Conoflow LB Valve Users:

ALUMINUM CO. OF AMERICA
AMERICAN CAN CO.
ARMOUR & CO.
ARMSTRONG CORK CO.
ATLAS POWDER CO.
BETHLEHEM STEEL CO.
CROSSETT PAPER MILLS, INC.
CROWN-ZELLERBACH CORP.
DOW CHEMICAL CO.
GENERAL FOODS CORP.
HAMMERMILL PAPER CO.
HERCULES POWDER CO.
JONES & LAUGHLIN STEEL CO.
KIMBERLY-CLARK CORP.
OLIN MATHIESON CHEM. CORP.
MERCK SHARP & DOHME
PABST BREWING CO.
REYNOLDS ALUMINUM CO.
JOS. SCHLITZ BREWING CO.
SCOTT PAPER CO.
SEAGRAM DISTILLERS CO.
E. R. SQUIBB & SONS
UNION CARBIDE CORP.
U. S. RUBBER CO.
U. S. STEEL CORP.
WEYERHAEUSER TIMBER CO.

CC803

CONOFLOW CORPORATION
FOREMOST IN FINAL CONTROL ELEMENTS

SUBSIDIARY WALWORTH



It takes Tough Testing to build Timing Performance

When you buy a Haydon Timing Motor or Timing Device, you buy high quality and superior performance, because every production model and every new design has *proved* itself by passing the toughest, most exhaustive series of tests that our engineers can devise.

Quality control at Haydon starts with a careful inspection of all in-coming materials. It continues throughout production — with all parts and assemblies gaged, inspected or physically tested after every operation that can affect the performance of the finished motor or device. Final step is an inspection of completed motors and timing devices. All units are performance tested for many hours under varying conditions and are checked for quiet operation. Percentage samples of each lot are checked for torque rating, timing accuracy, and accuracy and alignment of gears and shafts. In addition, all new designs and periodic samplings from production are subjected to special "life endurance" tests in which hundreds of units are run continuously under various load conditions. In some instances, units have now been running ceaselessly for more than 10 years . . . proving their ability to perform *millions of cycles without failure!*

When you submit your timing problems to Haydon, you can be certain that our teams of engineers and other Timing Specialists have the experience, knowledge and facilities to supply devices designed, produced *and* tested to meet your needs exactly and perform according to your specifications.

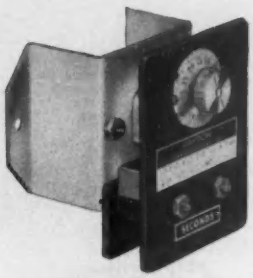
For further information, write now, outlining your timing requirements.

Haydon
AT TORRINGTON

DIVISION OF GENERAL TIME CORPORATION

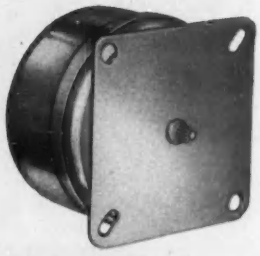
2333 EAST ELM STREET
TORRINGTON, CONNECTICUT

Headquarters for Timing



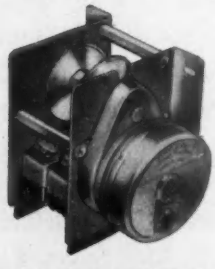
TIME DELAY TIMER

Provides time delay in ranges up to 9.5 minutes. Ideal for such applications as the protection of power tubes and/or operating preset operating cycles. Available in 120 or 240 volt, 50 or 60 cycle current.



400 CYCLE MOTOR

These split phase motors provide the military an accurate approach to timing control for military applications. Rotor speed is 3,000 RPM at 400 cycles, 115 volt normal. Two models are available — Heavy Duty with 18 gram millimeters torque at the rotor, and the Miniature with 5 gram millimeters at the rotor. These motors may be applied to Haydon gear trains if desired.



CYCLE TIMER

These units repeat a set cycle or sequence of operations as long as the motor is energized. Available in a wide choice of speeds, a broad range of timing intervals, and with a wide range of enclosed single pole, double throw switches for 120 and 240 volt operation, for 50 and 60 cycles.

A HOFFMAN SEMICONDUCTOR APPLICATION CASE HISTORY

THIS CONTROL PROBLEM HAD TO BE SOLVED

FOR AUTOMATIC DOLLAR BILL CHANGERS

Hoffman Silicon Solar Cells were the solution

A.B.T.'s (division of Atwood Vacuum Machine Co., Rockford, Illinois) intricate control problem in their unique "bill changer" required Hoffman Silicon Solar Cells, of exacting quality, to automatically register the authenticity of a dollar bill, in this innovation in automatic vending.

You, too, may have a control problem requiring immediate and accurate registering—instantaneous response (20 microseconds)—long life (10,000 years*)—high light conversion efficiency (up to 10%)—wide spectral response range (4,000-11,500 angstroms)—extended operating temperature range (—65°C to +175°C).

Hoffman Silicon Solar Cells, born from the same family as those which are still powering the U. S. Navy's Vanguard satellite's radio transmitter, can be the answer to your control problem. For details consult the Hoffman Solar Cell applications specialist in your area or write to Department SS.

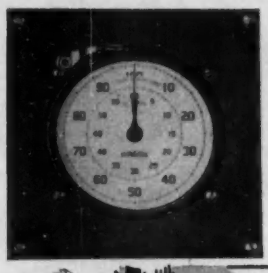
If you need a job in electronics done quicker and better, contact

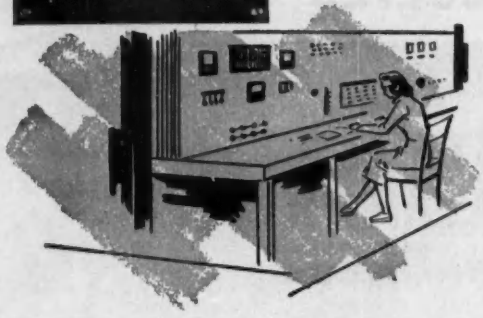
Hoffman Electronics CORPORATION
SEMICONDUCTOR DIVISION
930 PITNER AVENUE EVANSTON, ILLINOIS

*(Per R.C.A. Laboratories, Princeton, New Jersey, Report No. 212-PH-55-91 [1114], April 15, 1955)

CIRCLE 68 ON READER-SERVICE CARD

STANDARD ...SYNONYM for PRECISION in TIMING





For timing requirements in research, testing or production . . . if the need for *precision* is paramount . . . the choice is STANDARD.

Recognized as THE criterion by which other timers are judged (and *calibrated*), STANDARD Elapsed Time Indicators are noted for their long life under continuous use.

Large enough to work with handily and read readily, STANDARD timers are electric clutch controlled by manual or automatic switch or by electric circuits or output of electronic tubes. Units are synchronous motor driven . . . available for flush panel mounting or portable use . . . equipped for manual or electric zero reset.

For ultra precision timing with AC current, models available for 400 CPS operation. Also available: 400 CPS power supply operating from DC source.

MODEL	SCALE DIVISIONS	TOTALIZES	ACCURACY
S-100	1/5 sec.	6000 sec.	±.1 sec.
S-60	1/5 sec.	60 min.	±.1 sec.
SM-60	1/100 min.	60 min.	±.002 min.
S-10	1/10 sec.	1000 sec.	±.02 sec.
S-6	1/1000 min.	10 min.	±.0002 min.
S-1	1/100 sec.	60 sec.	±.01 sec.
MST	1/1000 sec.	.360 sec.	±.001 sec.
MST-500	1/1000 sec.	30 sec.	±.002 sec.

Request descriptive Catalog No. 198

THE STANDARD ELECTRIC TIME COMPANY | 89 LOGAN STREET SPRINGFIELD, MASSACHUSETTS

Travelling Display—Watch for showing in your area. See complete STANDARD Systems in operation.

ALSO MANUFACTURERS OF:

Emergency Lighting Equipment

Laboratory Panels

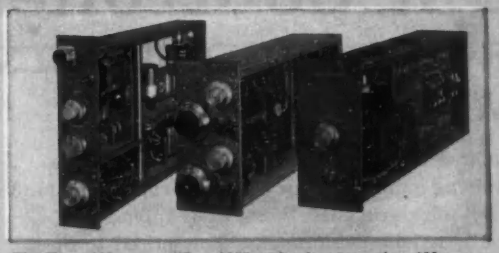
Hospital Signalling Equipment

Analogue Computors

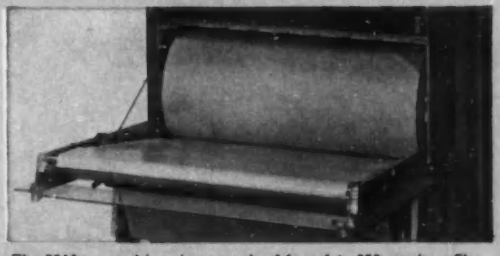
Precision Timers

the most versatile . . . most sensitive direct writing unit available!

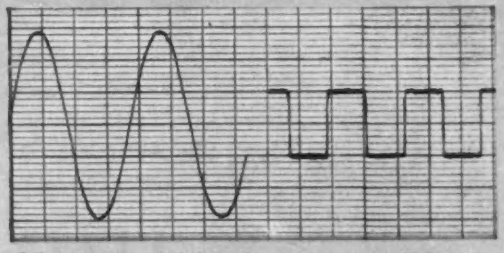
OFFNER ALL-TRANSISTOR R DYNOGRAPH



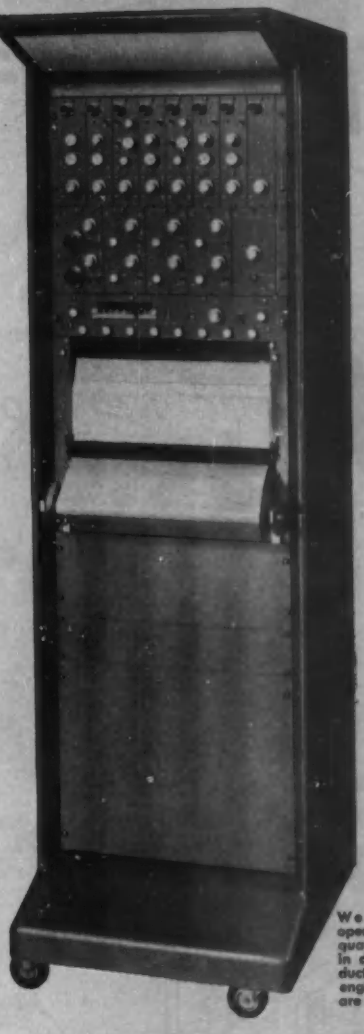
The Type 481 preamplifier, 9800 series input coupler, 482 power amplifier, and 382 power supply are all of plug-in construction. Input is available both front and rear.



The 504A paper drive gives speeds of from 1 to 250 mm/sec. Electrical speed shift 1 to 250 mm per minute available. Zero weave high precision drive, 850 ft. capacity (heat or electric) 1500 ft. (ink). Front loading, with record fully visible from front.



Full scale, unretouched charts show the extreme sensitivity of the Type R Dynograph. Left—10 microvolt RMS sine wave. Right—10 microvolt D-C square wave. Four recording media. Heat or electric rectilinear—ink or electric curvilinear. Readily convertible.



We have a few openings for *highly qualified* engineers in development, production, and sales engineering. Inquiries are invited.

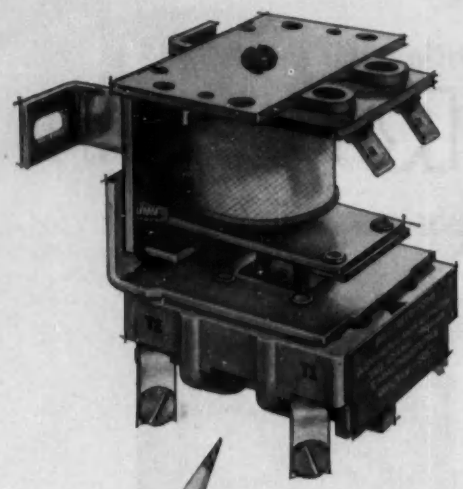
all these features . . . plus 8 channels in only 35″ of rack space

- stable d-c sensitivity of one microvolt per mm
- true differential input
- high input impedance
- response to beyond 150 cps
- reluctance, differential transformer, strain gages with a-c or d-c excitation, thermocouples, etc., used with all preamplifiers
- deflection time less than 1.5 milliseconds (2.5 ms with preamplifiers)
- fixed precision calibration
- instant warm-up
- precision source for d-c and 400 cycle excitation, self-contained
- zero suppression, twenty times full scale, both directions

Whatever your application for direct writing records, investigate the ability of the Offner Type R Dynograph to do the job *better* and more *simply*. Write on your company letterhead for details and specifications.

OFFNER ELECTRONICS INC. 3904 River Road, Schiller Park, Ill. (Suburb of Chicago)

CIRCLE 70 ON READER-SERVICE CARD



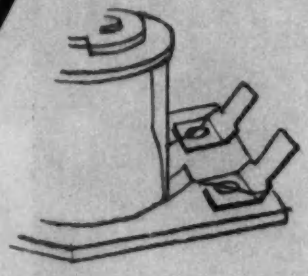
Thrifty New Type 80

E ESSEX ENGINEERED E

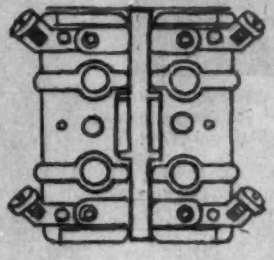
RBM Controller
FOR AIR CONDITIONING COMPRESSORS

Here is another RBM development exclusively for the air conditioning industry. Type 80 is a specific design for 3 HP or nominal 3-ton single phase compressor application. Exceptionally reliable performance. Low priced to meet needs of volume users.

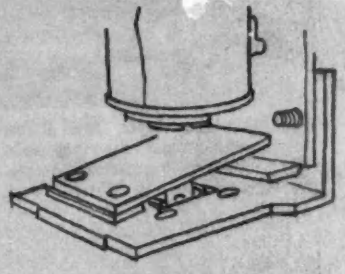
SOUNDLY DESIGNED FOR LONGEVITY AND RELIABILITY



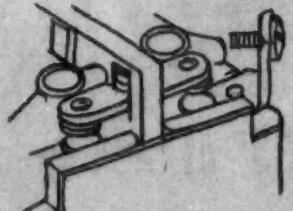
STANDARD ¼" QUICK CONNECT COIL TERMINALS OR LEAD WIRES (14")



POLE ARRANGEMENT 2 POLE N.O. ONLY



SPECIAL MAGNET DESIGN INSURES POSITIVE CONTACT ACTION-NO KISS POSITION



LARGE DOUBLE BREAK SILVER ALLOY CONTACTS

U/L LISTED FILE NO. E12139

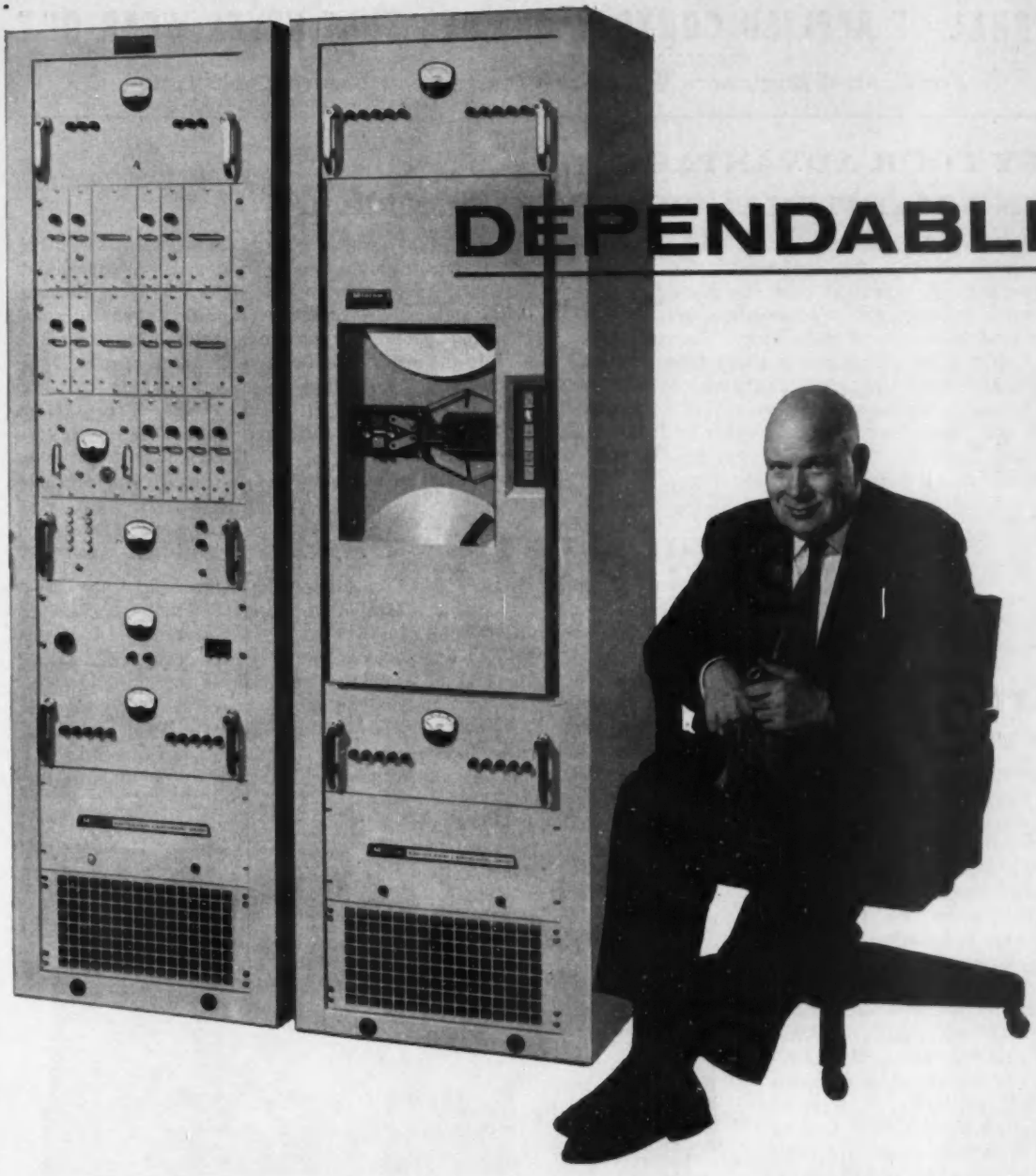
- ✓ DURABLE MELAMINE BLOCK AND CARRIER
- ✓ CONTACT RATING: 25 AMP. CONTINUOUS, 150 AMPS. INRUSH AT 250 V.A.C.
- ✓ CONTACT TERMINALS: SCREW TYPE
- ✓ COIL RATING: 24, 120, 208, 240 V. 60 CY.
- ✓ EXCEEDS RIGID REQUIREMENTS OF INDUSTRIES' LARGEST USERS

Consult Your Local RBM Product Application Engineer or Write For Bulletin No. C10

RBM **RBM Controls Division**

ESSEX WIRE CORPORATION, LOGANSPORT, INDIANA

Factories Located at Peru, North Manchester and Logansport, Indiana



DEPENDABLE

Dependable is the word for the new Mincom Model CV-100 Video Band Magnetic Tape Recorder Reproducer. Only 12 moving parts, four simple adjustments. No mechanical brakes. Seven 1-megacycle video channels on a single half-inch tape. Tape speed of 120 ips, coupled with specialized circuitry, produces a reliable frequency response from 400 cycles to 1.0 megacycle (each track). Signal-to-noise ratio: 30 db, peak signal to rms noise. All plug-in assemblies, carefree maintenance. Interested? Write Mincom today for specifications.

3M COMPANY ... WHERE RESEARCH IS THE KEY TO TOMORROW

MINCOM DIVISION MINNESOTA MINING AND MANUFACTURING COMPANY

2049 SOUTH BARRINGTON AVENUE • LOS ANGELES 25, CALIFORNIA

CIRCLE 72 ON READER-SERVICE CARD

JOURNAL OF APPLIED CONTROL DEVICES THAT NEVER WEAR OUT

For Control Engineers Who Are Wearing Out Before Their Time

THEY TOOK ADVANTAGE OF (NO MAINTENANCE) STATIC CONTROL

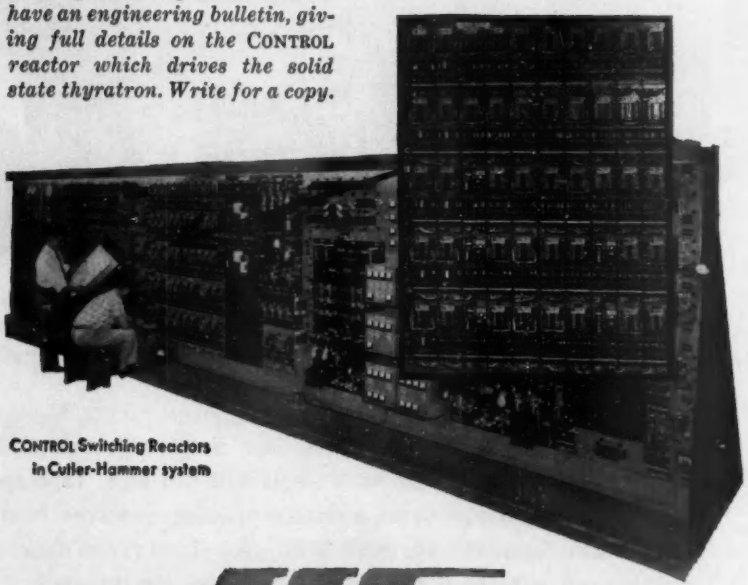
Cutler-Hammer, Inc. and Arthur G. McKee & Co., American experts at control system and steel mill design, respectively, have just paid due respect to the problem of servicing complex automatic equipment in a foreign land thousands of miles away. They have installed CONTROL Switching Reactors and Transductors in the blast furnace automatic charging control designed for an Argentine steel company. Why? Because under normal operation, CONTROL Switching Reactors simply don't wear out! Yet look what they do: (1) They sequentially count charges and other functions and register this information on the operator's control panel; (2) through logic switching, they control and interlock the static skip hoist drive, the blast furnace large and small bell actuators, the automatic coke charging system, and the alarm system . . . tying them all into the operational cycle of the blast furnace. *This is static control, so named because Switching Reactors have no moving parts. Totally enclosed, these high permeability magnetic devices operate in the gritty, corrosive atmosphere of the steel mill with never a shutdown for maintenance. Want details? Write us.*

THREE LITTLE WORDS–*logic, switch, operate*

If you want some insight into Cutler-Hammer's insight, there are three words (above) to pay special attention to. *Logic:* CONTROL's Switching Reactors are designed to take a variety of input signals to be fed into several isolated control windings and thus provide AND, OR, NOT, MEMORY and TIME DELAY sequences. *Switch:* Orthonol® cores provide stiff snap action going from "off" to "on" states. The power switching ratio is 2500:1, even under 10% over-voltage conditions. *Operate:* There's no need for auxiliary hardware. CONTROL reactors directly operate such loads as solenoids, motor contactors and magnetic clutches. They're ideal for the solid state thryratron. They handle single loads up to 300VA. *We have an engineering bulletin, giving full details on the* CONTROL *reactor which drives the solid state thyratron. Write for a copy.*

STATIC CONTROL: *simple and standard*

From where do your signal pulses come? Limit switches? Push buttons? Relays? Any transducer with an electrical output? The CONTROL Switching Reactor compiles them, remembers them, and then acts (logically) when the right one comes along. It's a selective device, for by presetting it, you will insure its operating only upon the proper combination of signals. The result? A CONTROL Switching Reactor will replace a relay system, and once replaced, you minimize maintenance and other old-fashioned worries. *And there's a size for every need up to 300VA output. There are* CONTROL *reactors which operate from standard line voltages, others which deliver standard load voltages, and now there's one which takes 120 volts in and gives 120 volts out! Full details? Your copy of our catalog awaits your request.*



CONTROL Switching Reactors in Cutler-Hammer system

Reliability begins with CONTROL

A DIVISION OF MAGNETICS, INC

DEPT. CE-77, BUTLER, PENNSYLVANIA

COMPUTER PROGRESS FROM GENERAL ELECTRIC

ANNOUNCING THE FLEXIBLE NEW GE 312 DIGITAL CONTROL COMPUTER FOR ON-LINE PROCESS COMPUTING APPLICATION IN INDUSTRIAL AND UTILITY SYSTEMS

GE 312 DIGITAL CONTROL COMPUTER

GENERAL ELECTRIC PROCESS CONTROL AUTOMATED BY GENERAL ELECTRIC

Newest member of a distinguished family of General Electric computers, the GE 312 *transistorized* DIGITAL CONTROL COMPUTER has been especially designed for process control, data logging, and data processing requirements imposed by industrial and utility operation.

• "Big Machine" features--moderate in cost • Expansible memory capacity
• Easily programmed • Advanced programming aids available • Rugged construction for industrial application • Off-line operation as a general purpose computer

Request brochure CPB-36A. For more information on computers, computing control and automation, contact your nearest General Electric Apparatus Sales Division Office, or write to: Computer Department, Room 7700AB General Electric Company • Deer Valley Park • Phoenix, Arizona.

Progress Is Our Most Important Product

GENERAL ELECTRIC

FOR FIGURES IN A HURRY—FIGURE ON A GE COMPUTER

CIRCLE 74 ON READER-SERVICE CARD

Read up to 288 temperatures at this Honeywell "Operator's Desk"

This compact console type Operator's Desk makes it possible, from one central location, to read as many as 288 thermocouple points, or 192 points with identifying card holders. Its *ElectroniK* Precision Indicator and switch assemblies are mounted for ease of reading whether the operator is sitting or standing.

The *ElectroniK* Precision Indicator, accurate to 1/5 of 1% of full scale, can be of single range, double range or extended range type. Use it with all types of thermocouples, millivolt actuation, or a combination of the two. The desk can be supplied with a telephone dial system for thermocouple selection, rather than key or pushbutton switches. Additional equipment such as lights and clocks can be built in.

Servicing is simplified. Instrument and switch terminal blocks are in the lower rear portion of the desk, readily accessible from the back of the console. All wiring enters from the bottom of this compartment.

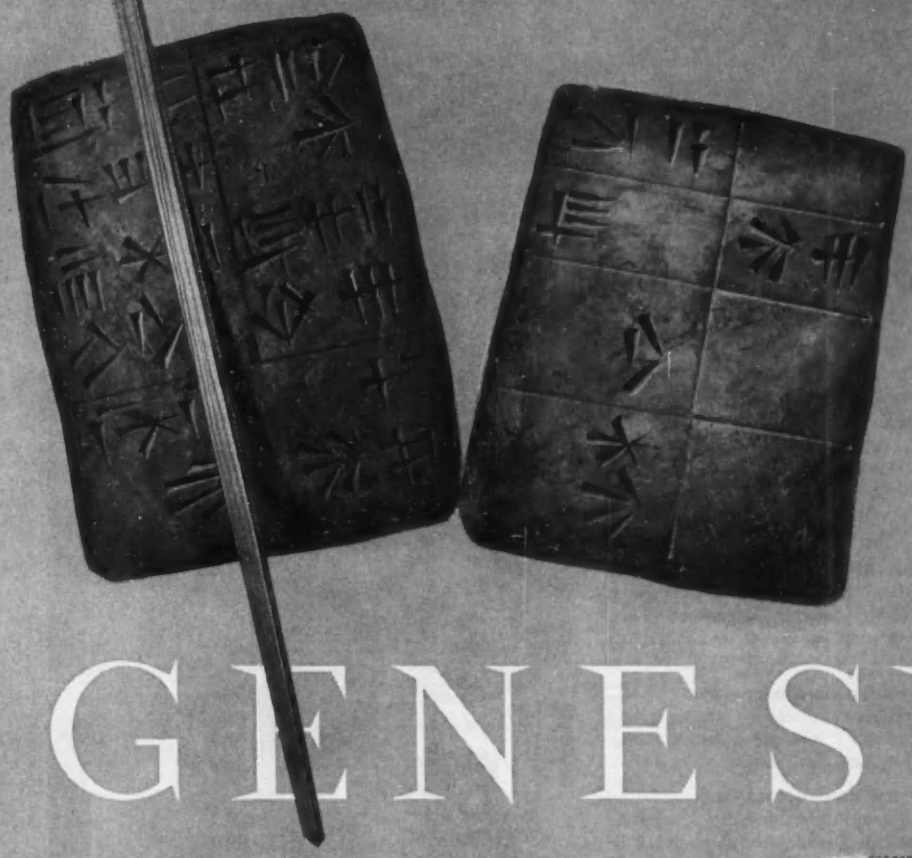
Get complete details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

First in Control

PRACTICAL PROCESS CONTROL



GENESYS

Designed from inception for process control, Genesys advanced digital control computer systems provide many exclusive advantages with unprecedented economy. Knowledge of precise process dynamics is not required. You can *optimize* process operations using your present instrumentation. You get unmatched reliability through practical design, practical computer speed matched to the problem – thus fewer and only the most proven components. Genesys Systems deliver 4,000 hours of continuous, non-stop operation between scheduled maintenance periods . . . dependability with simplicity of operation at low cost . . . seven giant steps forward in process and pipeline automation. Write for "Evolution in Process Control."

Filling the void in practical digital control, this Unit Memory Processor (UMP) is the heart of a Genesys Process Control System, uses the best combination of general purpose and incremental computer techniques.

GENESYS CORPORATION

10131 NATIONAL BLVD., LOS ANGELES 34, CALIFORNIA

A Subsidiary of CHANCE VOUGHT AIRCRAFT

BASIC REQUIREMENTS
for outer space

The space/missile era has made it essential for today's components and systems to function precisely in environments that are literally out-of-this-world. Such stringent requirements can only be met by companies long experienced in component design and with proved records of imaginative engineering. Kearfott, long the leader in servo component design and production, has consistently looked into the future to anticipate the increased performance characteristics missile components must supply. As a result, it has not only developed an entirely new generation of precision components but established the ability to create radically new concepts in sensors and control elements.

THE PROBLEM: **HIGH ACCURACY**
THE SOLUTION: Synchros with maximum error from electrical zero of 20 seconds. Tachometers with linearity .05% over the speed and temperature range.

THE PROBLEM: **HIGH AND LOW TEMPERATURE**
THE SOLUTION: Servomotors, synchros and tachometers are now available for the temperature range of −54° C to 200° C with new developments soon to increase the range to 400° C.

THE PROBLEM: **RADIATION RESISTANCE**
THE SOLUTION: Kearfott servomotors, synchros and tachometers operate at 200° C and can withstand radiation of 10^8 through 10^{10} roentgens.

THE PROBLEM: **SHOCK AND VIBRATION**
THE SOLUTION: All Kearfott components can be supplied to function as required during or after 20 g's shock or 2000 cps vibration.

THE PROBLEM: **MINIATURIZATION**
THE SOLUTION: Size 5 synchros and servomotors. Size 8 components are outstanding examples of Kearfott's ability to combine miniaturization with precise performance.

THE PROBLEM: **LONG LIFE**
THE SOLUTION: Components are being developed which will operate continuously for 12 months in a total vacuum, the environment of outer space.

Representative of Kearfott's ability to look ahead are such current areas of development as Solid State Transducers and Control System Components. **You can take advantage of Kearfott's long-established know how in developing precision components for today — and tomorrow — by writing for details concerning your specific requirements.**

Engineers: Kearfott offers challenging opportunities in advanced component and system development.

Kearfott | A GENERAL PRECISION COMPANY

KEARFOTT COMPANY, INC., LITTLE FALLS, N. J.
A subsidiary of General Precision Equipment Corporation
Sales and Engineering Offices: 1500 Main Avenue, Clifton, N. J.
Midwest Office: 23 W. Calendar Avenue, La Grange, Illinois
South Central Office: 6211 Denton Drive, Dallas, Texas
West Coast Office: 253 N. Vinedo Avenue, Pasadena, California

HOW MANY DROPS MAKE A LEAK?

Front Panel — Electrical Control Assembly

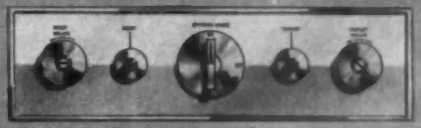
All-New CI LEAKMETER *Automatically Measures Hydraulic or Fuel Leakage!*

The measurement of leakage by counting or gauging drops is now obsolete! Convair Instruments' all-new LEAKMETER Model 400, when installed in a line between a pressure source and the system or component under test, will positively indicate, by a signal light, the presence of a leak, and will accurately measure its magnitude.

Operation of the LEAKMETER is automatic with a built-in timer which can be set for periods of 15 seconds to 5 minutes, providing a range for the instrument of 0.008 to 80 cc per minute. To measure other rates of leakage, or to test for sustained zero leakage, the timer may be overridden and the test conducted over any desired period.

PRINCIPLE: Fluid leakage is translated by a displacement transducer into a proportional electrical signal which is indicated in cubic centimeters by a meter housed in an electrical control unit. **EASE OF OPERATION:** The hydraulic transducer assembly is packaged separately from the electrical control assembly, permitting remote location. Both are designed for standard rack mounting. The hydraulic assembly is connected by quick-disconnect fittings.

COMPATIBILITY: The LEAKMETER is compatible with all common hydraulic fluids and fuels. Because both assemblies are isolated from the test environment, the item under test may be subjected to shock, vibration, or high temperatures. **TEST PRESSURES:** Accommodates test pressures to 5000 psi. **OPTIONAL READOUT:** Jacks are provided for recording or other readout. **PROVEN:** In use by leading manufacturers of high performance hydraulic equipment.



Front Panel — Hydraulic Transducer Assembly

For COMPLETE INFORMATION: Write, wire, or phone:

CONVAIR INSTRUMENTS / CONVAIR, A DIVISION OF GENERAL DYNAMICS CORPORATION

3595 Frontier Street, San Diego, California
ACademy 3-1614

ELECTROMECHANICAL AND MECHANICAL INSTRUMENTS;
AC AND DC MEASURING DEVICES, TRANSDUCERS.

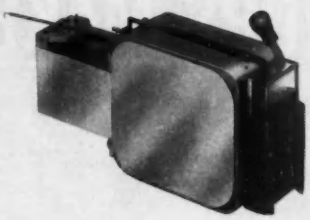
MASSA

HIGH SPEED RECORDING SYSTEMS

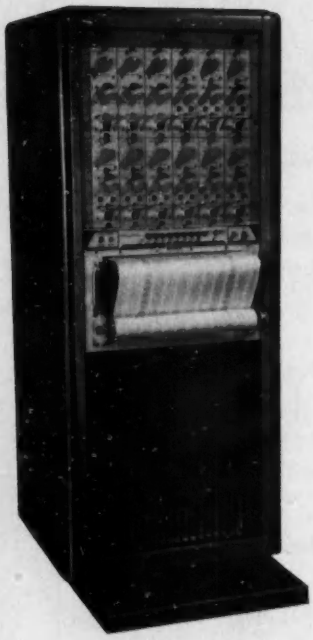
WITH EXCLUSIVE

INK WRITING RECTILINEAR OSCILLOGRAPHS

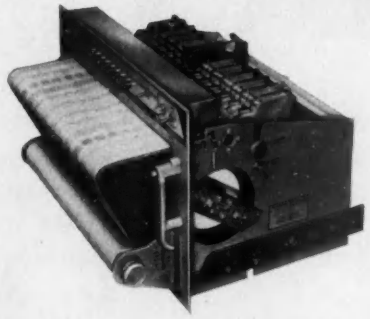
ALL OSCILLOGRAPHS use the basic acoustically damped electro-dynamic system with a linkage arrangement to produce true rectilinear displacement of the writing pen. Because of its small size and light weight these oscillographs have found many useful applications never before realized. Dimensions: 4⅝"L x 1¼"W x 3¼"H (pen overhangs 1") Weight: 1½ lbs.

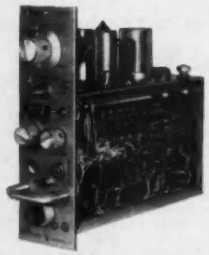


MASSA METERITE Modular 2-channel Portable Recording System, Model BSA 200 with transistorized driver amplifiers, features interchangeable plug-in preamplifiers. Low, medium and high gain DC; AC; Chopper; Carrier; or Servo preamplifiers are compatible with this direct writing recorder. Full scale amplitude to 100 cps; reduced amplitudes to 200 cps are available. Six chart speeds (range .5 - 200 mm/sec). Dimensions: 14"W x 10"H x 16"D. Weight: About 35 lbs.



12-CHANNEL RECTILINEAR RECORDER, MODEL RE-12, (right) has been developed for a wide variety of high speed recording applications. Adaptable for rack mounting, with push button release handles, it is shown in cabinet mounting (left) as part of a compact 12-channel recording system. Wide frequency range reproduces signals from DC to 200 cps. Push button selection of 18 chart speeds from ½ cm/hr to 200 mm/sec. Event marker provides automatic 1 second markings on chart. Remote operation with plug-in control unit. Dimensions: 19"W x 12¼"H x 15"D. Weight: 56 lbs.





PLUG-IN PRE-AMPLIFIERS
Model PR-100 is a coupling device which, used with Driver Amplifier Model DA-100 (included in Basic System Assembly) provides a complete low gain DC amplifier channel.
Other Pre-amplifiers which are equally compatible with the Massa multi-channel systems can be made available upon order.

These pre-amplifiers with drivers are available separately in portable packages.

Recorder Accessories and Supplies are available including Power Supplies for Electric Writing; Chart Rolls with true rectangular coordinates for ink and electric writing; Pens and Styli; Disposable Ink Cartridges; Remote Control Units.

At ISA SHOW—Visit our Booth No. 751

MASSA
A DIVISION OF
COHU
ELECTRONICS INC

Other MASSA Products —

- SONAR TRANSDUCERS • ACCELEROMETERS • MICROPHONES • HYDROPHONES • AMPLIFIERS
- COMPLETE LINE OF MULTI-CHANNEL AND PORTABLE RECORDING SYSTEMS

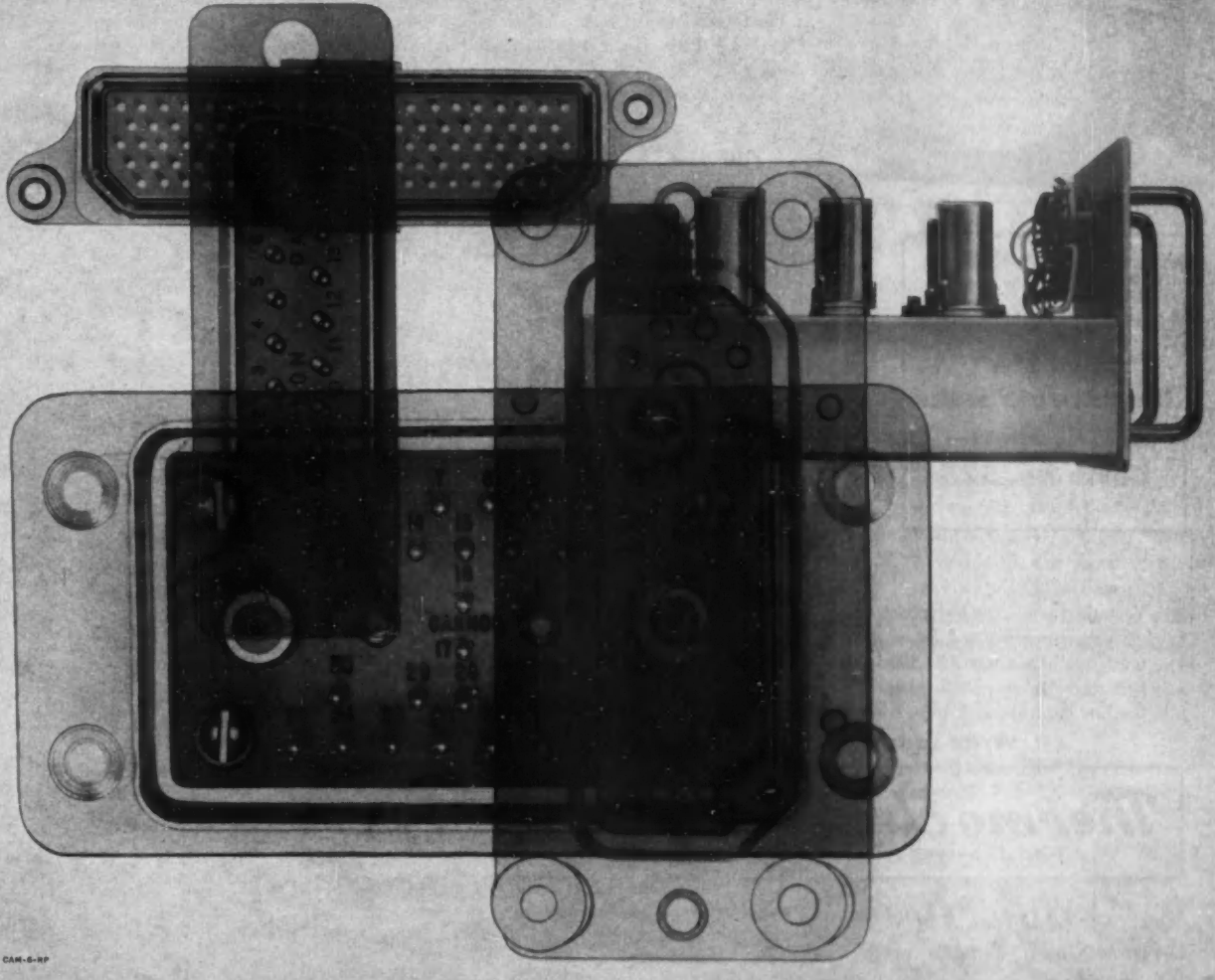
8 FOTTLER ROAD
HINGHAM, MASSACHUSETTS

CIRCLE 79 ON READER-SERVICE CARD
CIRCLE 80 ON READER-SERVICE CARD→

CANNON PLUGS

The assembling of highly-flexible electronic systems and subsystems into a modular package . . . for fast inspection, testing, service, and replacement of components . . . calls for standardized-type plugs throughout the system. Reliability and optimum flexibility in shell designs and types of layouts are the design criteria for the more than 18 different basic Cannon Modular and Rack/Panel Plug Series. This Series is available in standard, miniature, or subminiature sizes . . . for standard or printed circuitry. Up to 180 contacts and a varied combination of contacts for control, audio, thermocouple, co-ax, twin-ax, and pneumatic connections. Single or double-gang. With or without shells. The Rack/Panel Series ranges from the tiny "D" subminiature to the heavy-duty DPD Rack/Panel Plug. For further information on Cannon Modular and Rack/Panel Plugs write for Cannon DP Catalog, Cannon Electric Co., 3208 Humboldt St., Los Angeles 31. Please refer to Dept. 00. Factories in Los Angeles, Santa Ana, Salem, Toronto, London, Paris, Melbourne, Tokyo. Distributors and Representatives in the principal cities of the world.

Maximum Flexibility for Modular and Rack/Panel Applications



CAN-6-RP

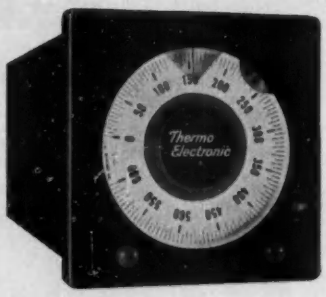
Design does make a difference

in the NEW Thermo® Electronic

Signaling Controller
Self Balancing Indicator
Indicating Recorder

Modern design—proven components—these are the hallmark of the new Thermo Electronic Instruments. And the proof of the pudding, in this case, is in the applicability.

No matter what your process measuring requirements, these instruments will prove unsurpassed for versatility, dependability, long-lived accuracy, sensitivity and speed of response. They will measure any variable translated to DC potential, current or resistance. The instruments have been specially designed for front-set adjustment, ease of operation and maintenance, quick, in-the-field, interchangeability of components and ranges, (from 1 to 100 millivolts). Accuracy is ±0.25% of full scale—sensitivity is ±0.125%. The exclusive new high-gain amplifier, which couples extreme sensitivity with exceptional stability, is utilized in each instrument.

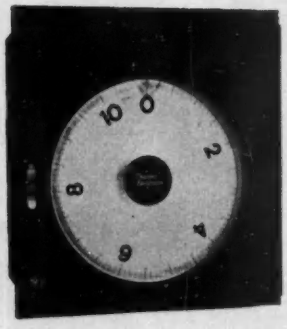


Size

Signaling Controller
Off-on, Potentiometer or Bridge Type

Takes just 56 square inches of panel space. Rugged, compact Signaling Controller automatically, continuously controls any process through DC signaling transducers. Corrective action is almost simultaneous with even a 1 microvolt signal change. Bright red-green lights show process condition. Provides built-in fail-safe action—fully automatic reference junction compensation.

See these and many other Thermo Electric Instruments at the I.S.A. Show— Booth No. 525



Readability

Self Balancing Indicator
Potentiometer or Bridge Type

Rapidly, automatically indicates condition at any one of several hundred sensing elements connected through multi-point switches. Large 34″ scale is easily seen from a distance. Built-in fail-safe action—optional 2 or 3 position controls—up to 6 alarm contacts available.

Versatility

Indicating Recorder
Potentiometer or Bridge Type

Versatility personified, the Indicating Recorder will automatically indicate and record any variable converted to a DC voltage or resistance change. Fine-line recording pen rarely needs refilling. Large 34″ dial is clearly visible from a distance. Full scale pointer and pen travel takes just 5 seconds. Provides built-in fail-safe action—optional 2 or 3 position controls, and up to 6 alarm contacts.

Write today for Bulletin 156-B

Thermo Electric CO., INC. SADDLE BROOK, NEW JERSEY
In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ontario

Key building block in flexible process control...

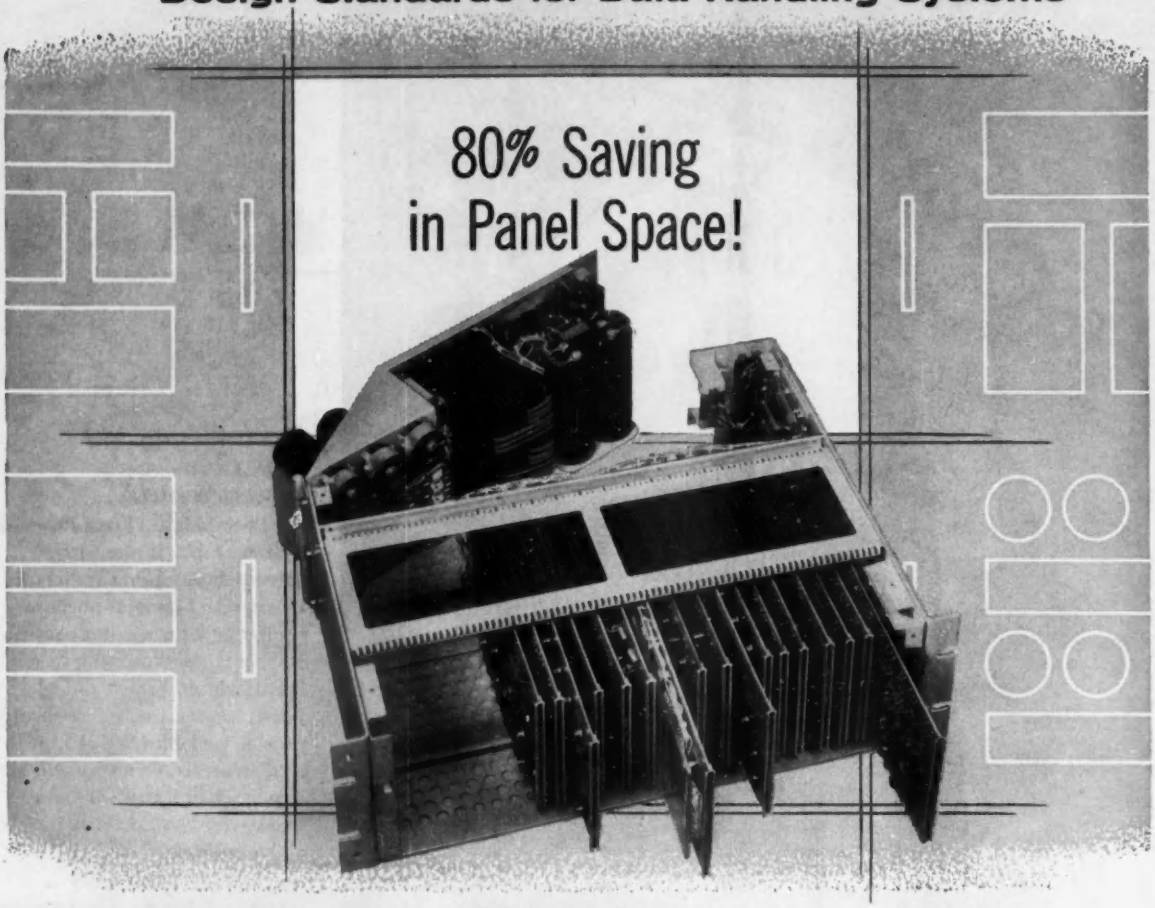
the Beckman 123 Data Processing System. ⌘ Use it alone for process data logging and alarming. Use it with a general-purpose computer for computer control. Its flexibility allows you to first study and then control your process...as well as modify process variables and easily reset controls. ⌘ In addition to this flexibility, the 123 Data Processing System offers all-transistorized circuits for maximum dependability... pinboard programming for ease of operation...100 or more channels to handle any logging problem...typewriter, paper tape, or punchcard readout... visual and audio alarms. ⌘ Let a Beckman stream-control specialist help you to a 1-2-3-4 building block solution to your process control needs... from sample handling (1) and stream analysis (2) through data processing (3) and digital computing (4) to an ultimate closed loop. For more information on the 123 Data Processing System or an on-stream survey, write for Data File 46-8-09.

Beckman
Scientific and Process Instruments Division
Beckman Instruments, Inc.
2500 Fullerton Road,
Fullerton, California

See this and other Beckman Products, Booth 446, Chicago ISA Show, Sept. 21-25.

CIRCLE 82 ON READER-SERVICE CARD

Magnetic Core Buffer Memory Sets New Design Standards for Data Handling Systems



Requires only 5¼" of Space in a 19" Rack

From General Ceramics—Four new magnetic core buffer memories that are setting new design standards among data handling system designers requiring increased efficiency in smaller physical packages.

Now available in either random access or sequential designs:

144 M4A — 144 characters in 9x16 array with a word length of four bits.
144 M8A — 144 characters in 9x16 array with a word length of eight bits.
512 M8A — 512 characters in 16x32 array with a word length of eight bits.
1024 M8A—1024 characters in 32x32 array with a word length of eight bits.

Design Features Include—

1. **SPACE-SAVING**—Require only 5¼" of standard rack space . . . permit smaller overall system design.
2. **VARIABLE CHARACTER AND BIT LENGTHS**—Unique design of driver circuit permits circuitry of existing data handling system to be enlarged without costly redesign.
3. **HIGHER OPERATING TEMPERATURE RANGE**—Contributes to miniaturized system design because memory functions satisfactorily under higher ambient temperature conditions.
4. **EASE OF MAINTENANCE**—All components are within easy reach. All circuits are on plug-in cards except power supply which is hinged across the back; swings out for easy accessibility.
5. **EXTRA FEATURES**—All units are equipped with an electronic clear and output register at no extra cost.

Complete detailed technical information will be supplied promptly on request. Please address inquiries to Dept. CE.

GENERAL CERAMICS
ORIGINATOR OF THE SQUARE LOOP FERRITE

Applied Logics Division
GENERAL CERAMICS CORPORATION
KEASBEY, NEW JERSEY, U.S.A.

electric motion control facts

for IDEA MEN

Warner brake, clutches, team with tape, control high-speed forward-reverse drive

Automatic film printer, with dual motor drive, speeds production, eliminates human errors

Here is an example of how 6-millisecond operation through overexcitation of the electromagnetic coils makes Warner electric brakes and clutches ideally suited for ultrasensitive tape-controlled servo-systems.

The problem was to design a robot printer which would reduce motion picture film processing time and eliminate human judgment in determining light exposure. Here is how that problem was solved.

First, a servodrive (Fig. 2) was designed to control light values automatically in accordance with the degree of negative exposure. This simple device, which provides two-directional movement of the selector arm over adjustable light value contacts, consists of two 1725 rpm motors, two flange-mounted Warner electric clutches, a Warner electric brake, and worm gearing.

A tape-controlled computer is an important part of the system. It transforms punched data into electrical signals which actuate the Warner electric brake and clutches.

Exposure values are compared by the computer with settings punched in the tape. A difference in values causes a bias —through a resistance network—on the grid of a thyratron tube. The tube fires a 200-volt burst (over twice normal magnet voltage) through the electrical circuit to the clutches.

The armature of each clutch is keyed to opposite ends of the worm gear shaft —the rotor to one of the constant-running power shafts. Actuation locks the armature and rotor of the desired clutch in full couple, transmitting power to the worm gear. This moves the shutter-control pointer in the proper direction. When the pointer reaches its preselected position, it completes a circuit and neutralizes the grid bias at the thyratron tube, cutting out the electric clutch. The brake (also mounted on the worm gear shaft) is actuated automatically when either clutch is de-energized. Required time for complete cycle is 6 milliseconds.

Ability to actuate Warner fractional-horsepower electric brakes and clutches directly through the operating power circuit may be the key to your space, timing, or cost problem. Complete automation can be achieved simply without complex control hardware—any electro-sensory device may be used to actuate a power drive precisely in a way that minimizes equipment cost and maintenance.

Your Warner sales engineer can help you solve difficult design problems with fast-acting, compact electric brakes and clutches. Contact him or send coupon below.

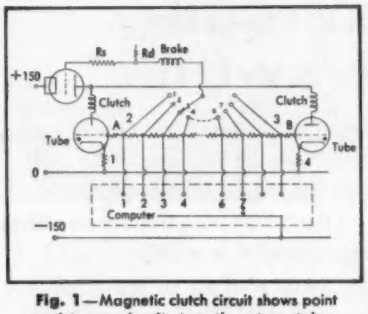


Fig. 1—Magnetic clutch circuit shows point resistance circuit, two thyratron tubes (A&B), computer, and power source hookup.

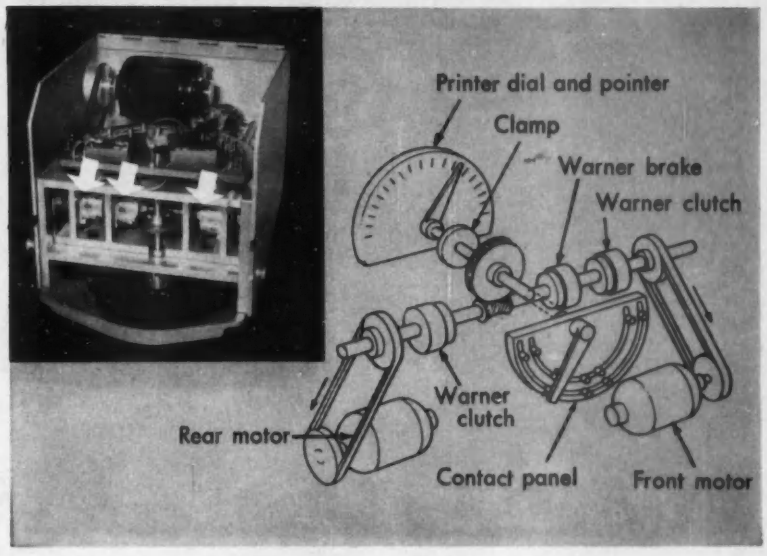


Fig. 2—Tape-controlled servomechanism locks on printer light value selection lever, automatically sets preselected exposure. Inset of servo-unit shows compact design made possible by use of Warner electric clutch-couplings and dual motor drive.

WARNER

Originators of electric motion control

Warner Electric Brake & Clutch Co.

Beloit, Wisconsin

Gentlemen: Please send complete information about Warner electric brakes and clutches.

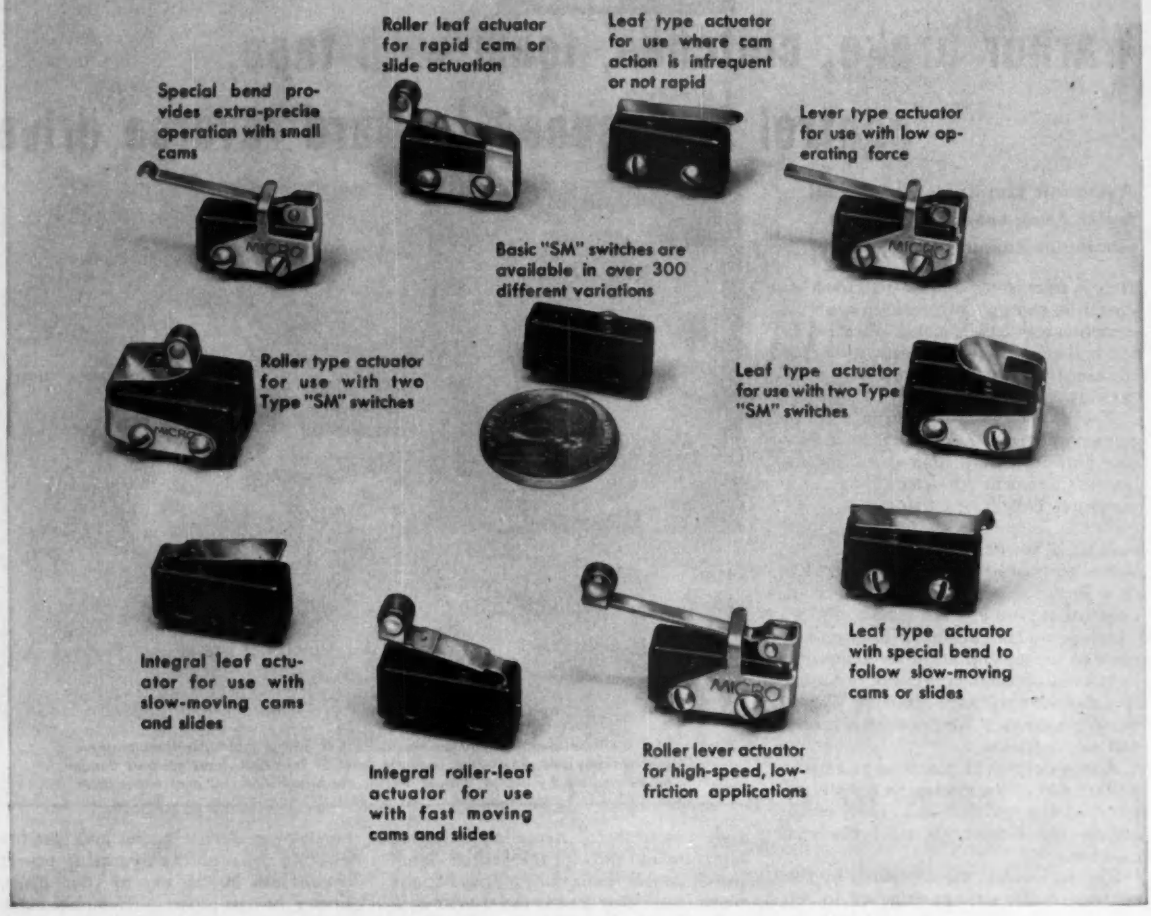
Name_____ Title_____

Company_____

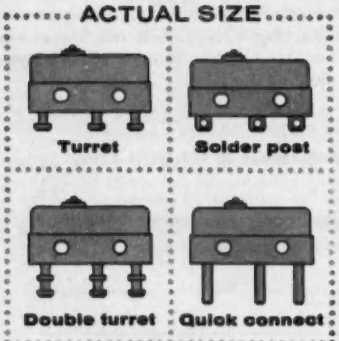
Address_____

City_____ Zone_____ State_____

MICRO SWITCH Precision Switches


Special bend provides extra-precise operation with small cams
Roller leaf actuator for rapid cam or slide actuation
Leaf type actuator for use where cam action is infrequent or not rapid
Lever type actuator for use with low operating force
Basic "SM" switches are available in over 300 different variations
Roller type actuator for use with two Type "SM" switches
Leaf type actuator for use with two Type "SM" switches
Integral leaf actuator for use with slow-moving cams and slides
Integral roller-leaf actuator for use with fast moving cams and slides
Roller lever actuator for high-speed, low-friction applications
Leaf type actuator with special bend to follow slow-moving cams or slides

Ten different ways to actuate this small, dependable switch



"SM" switches are available with these four kinds of terminals

Here are ten "SM" subminiature switches equipped with ten different integral and auxiliary actuators that contribute to the great versatility of these dependable, small switches. For ten years MICRO SWITCH subminiature switches have been the choice of designers who require switches of high electrical capacity which can be mounted in small space.

For complete information on the MICRO SWITCH lines of subminiature and sub-subminiature switches, we invite you to contact your nearby MICRO SWITCH branch office, or send for Catalog 63.

MICRO SWITCH . . . FREEPORT, ILLINOIS
A division of Honeywell
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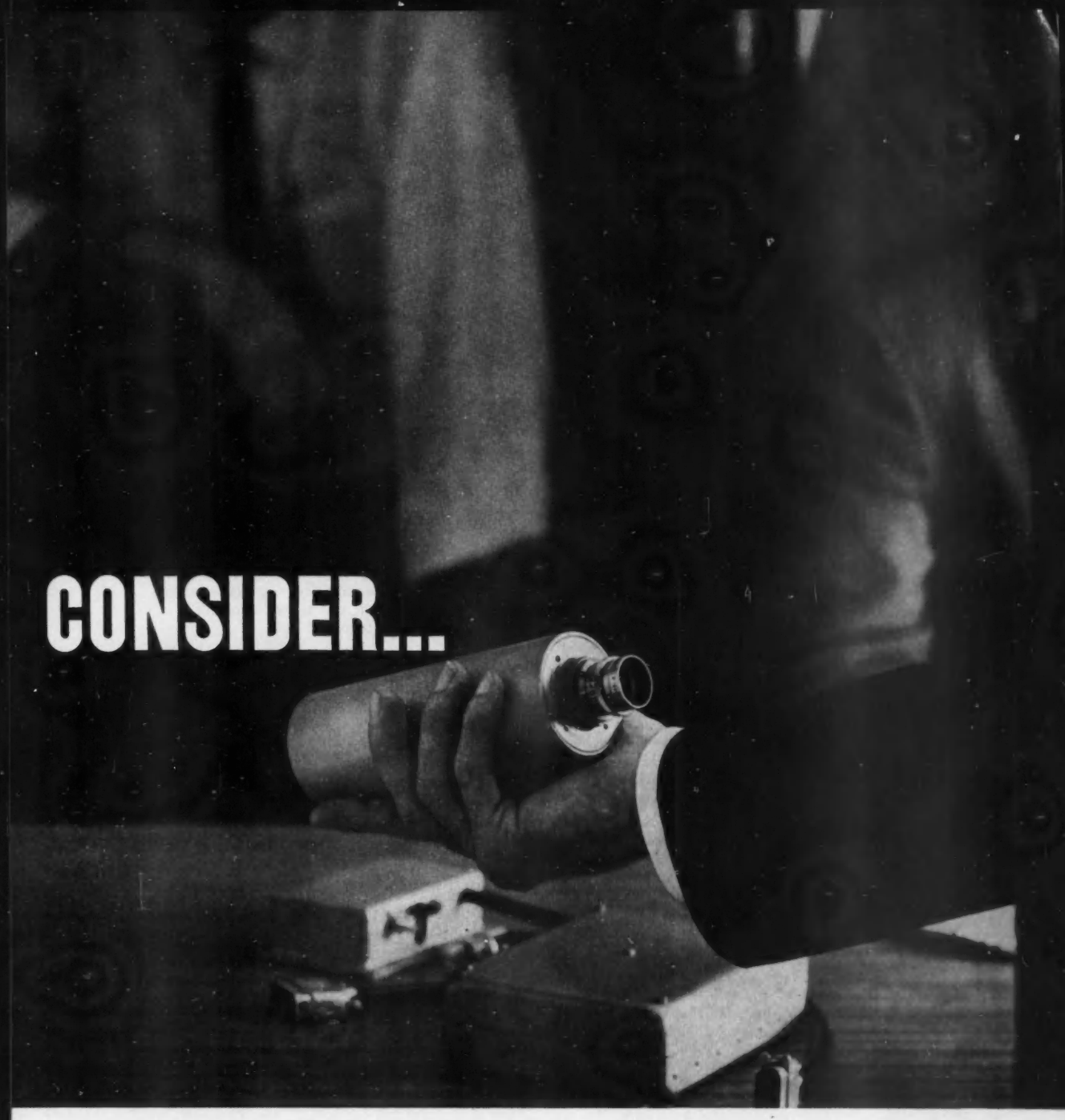
Honeywell
MICRO SWITCH Precision Switches



this rugged Video Telemetering System

THIS REMARKABLE NEW television system gives you the power of sight where human eyes cannot go. It can be directed outward for observation, or inward to "watch" internal operation from a range of 1,000 miles line-of-sight.

Capable of operation under extreme environmental conditions, and packaged for use under conditions requiring limited space, weight, and power, the Model 701 includes such features as: transistorized circuitry, 525 line, 30-frame fully interlaced picture, crystal controlled EIA synch, and high sensitivity.

Weight of the complete unit is under nine pounds. Total volume is less than 119 cubic inches. Its critical-design requirements are typical of all *LEAD* products. Each can be modified to meet many different requirements. Tell us what yours are. Contact our Marketing Branch, Lockheed Electronics & Avionics Division, 6201 E. Randolph St., Los Angeles 22...OVerbrook 5-7070.

Requirements exist for staff and supervisory engineers

LOCKHEED ELECTRONICS & AVIONICS DIVISION

Look to Lockheed for LEADership in Electronics

CIRCLE 86 ON READER-SERVICE CARD

AC / dc

. . . or the BEST of everything in process control

Swartwout pioneered electronic process control. It was evident that fully electronic control . . . with no signal lags, no dead bands, with infinite resolution in place of step changes . . . would offer the ultimate in process operation.

Swartwout's position was unique. As the first company, it had a clear field. The original research and development was free to select, test and determine the ideal circuit from countless combinations which were explored. Both AC and DC systems were built and tested.

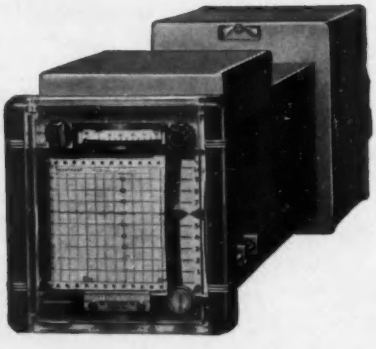
One combination emerged which incorporated the best characteristics for the control job: AC for the transmitter or sensor circuit because of its greater stability under high gains, the dependability of components, the trouble-free characteristics of the transmitter and the ease of explosion-proofing; then DC from the controller to the final element actuator.

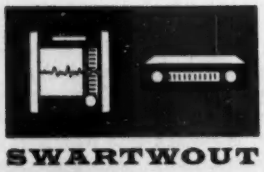
The series of patents issued to Swartwout are evidence of the originality of concept and of real contributions to the art.

Pioneering has its difficulties, but it has one overwhelming advantage over the late comers; it is unrestricted, it offers free choice . . . nothing desirable is locked out.

And this "best of everything" in concept is offered to you in the most practical design of the instrument itself.

You are years ahead with AutroniC Control . . . and you'll stay ahead with Swartwout leadership.





SWARTWOUT

. . . world leader in electronic process instrumentation

THE SWARTWOUT COMPANY
18511 EUCLID AVENUE,
CLEVELAND 12, OHIO

 CIRCLE 87 ON READER-SERVICE CARD CIRCLE 88 ON READER-SERVICE CARD→

THE NEW

SLO-SYN

SYNCHRONOUS MOTORS

AUTOMATIC MACHINES AND APPARATUS
needing a simple, efficient, maintenance-free synchronous motor

NUMERICAL CONTROL SYSTEMS
requiring continuous, constant-speed traverse and/or incremental stepping for positioning

REMOTE CONTROL SYSTEMS
using either manually-operated or remote positioning control

SERVOMECHANISMS
calling for instant starting, stopping and reversing characteristics without slip or chatter

72 RPM
shaft speed

STARTS
instantly!

REVERSES
instantly!

STOPS
instantly!

can be used as a stepping motor!

THE
SUPERIOR ELECTRIC
COMPANY

Bristol, Connecticut, U.S.A.

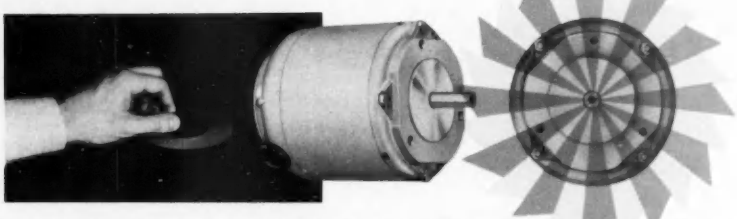
slo-syn SYNCHRONOUS MOTORS

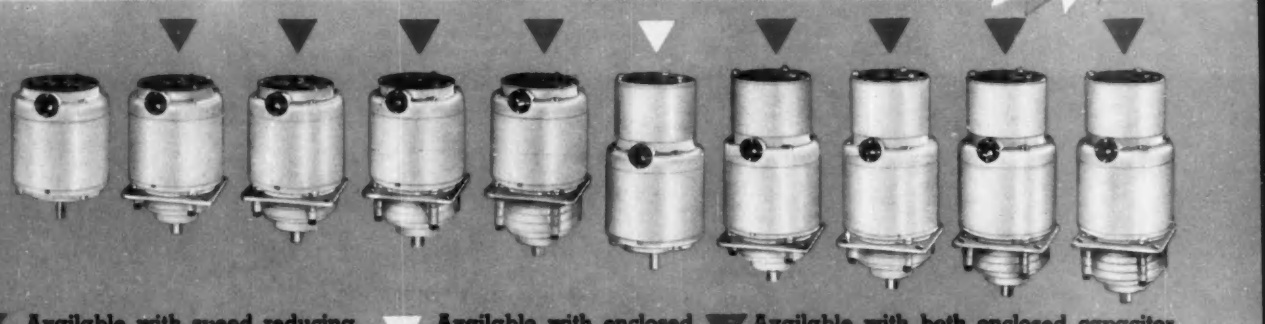
A SLO-SYN is an enclosed, permanent magnet type a-c motor with a slow basic shaft speed of 72 RPM. A single-pole, three-position switch can give complete forward, reverse and "off" control because the motor has three leads only. The SLO-SYN Motor will start or stop in less than 0.025 seconds or approximately 1.5 cycles. No need for electrical or mechanical braking because the motor will stop in less than 5° of shaft rotation. Maximum moment of inertia of a load rigidly attached to the shaft is 1.5 pound-inches². Loads with higher inertia can be started by using a coupling method which allows 5° freedom. Types having specially-designed planetary gear assemblies are available to provide speeds of 3.323, 0.665, 0.133 or 0.027 RPM. Torque on all planetary gear types is 2500 ounce-inches.

TYPE SS150

AS A D-C STEPPING MOTOR

The SLO-SYN Synchronous Motor can be adapted for use as an incremental stepping device by the use of a d-c power source and a suitable switching arrangement. When used as a control system stepping or "inching" motor, d-c electrical impulses are converted into either 200 or 400 precise increments of one revolution of the motor shaft. The motor will maintain its rated torque for any stepping position. Each step is made instantly without slip or clatter because no ratchets are used.



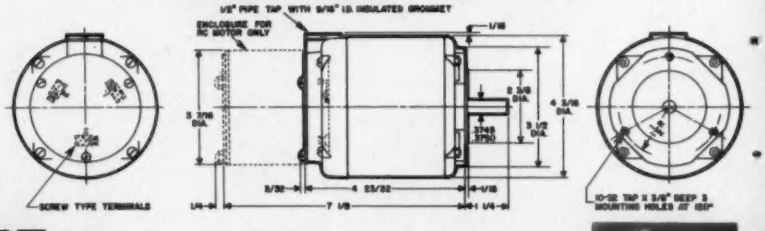


▼ Available with speed reducing planetary gears ▼ Available with enclosed capacitor and resistor ▼ Available with both enclosed capacitor and resistor and planetary gears

RATINGS AND SPECIFICATIONS

INPUT	120 volts, 40/70 cycles, 1 phase
OUTPUT SPEED	72 RPM at 60 cycles
MAX. CURRENT	0.3 ampere at 60 cycles
TORQUE	150 ounce-inches
WEIGHT	6.5 pounds

OUTLINE DIMENSIONS – TYPE SS150



THE SUPERIOR ELECTRIC COMPANY, Bristol, Connecticut

☐ Please send SLO-SYN Synchronous Motor Bulletin

☐ Please have your representative call.

name

company

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city zone state

... FOR YOUR FILES

Request SLO-SYN Bulletin giving full technical information, ratings and specifications.

THE SUPERIOR ELECTRIC COMPANY

Bristol, Connecticut, U.S.A.

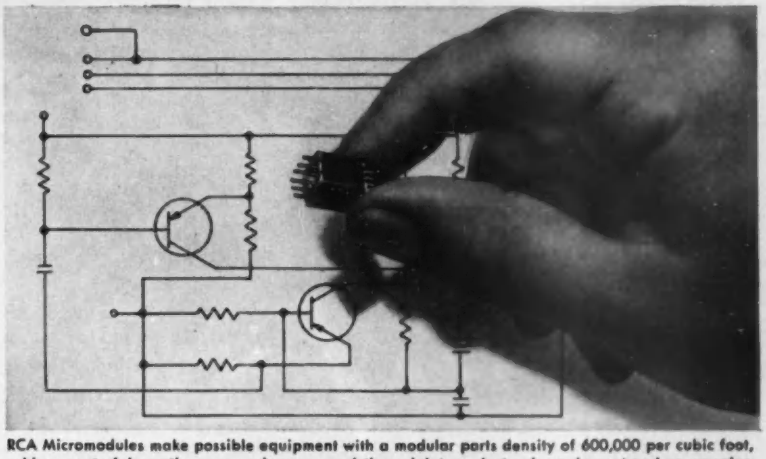
Status Report on RCA Micromodules—dramatic new semiconductor system for high-density parts packaging

Another Way RCA Serves Industry and the Military through Electronics

Now...600,000 Parts Per Cubic Foot In Low-Power Transistor Circuits with RCA Micromodules

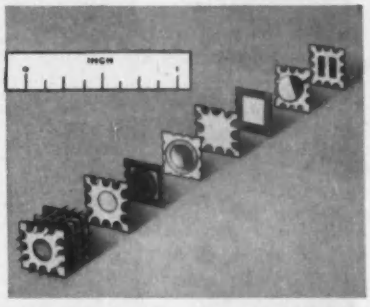
Since our March announcement of the availability of RCA Micromodules, we have been deluged with requests from equipment manufacturers to design their circuits into sample modules...and we are happy to do it, of course. That's the purpose of this first report—to let you know that we'd like to evaluate *your* new or existing circuits for micromodularization. Remember, micromodularized end-equipment for application in military computers, digital devices for missiles and satellites, airborne or portable communication equipment, or submarine electronics is probably only *one design cycle* away. That's why we want you to know *now* what we can do for you.

The inherent advantages of micromodularized equipment are among the most exciting in years. Now in pilot production, RCA Micromodules can be made for *any* low-power transistor circuit. The opportunity to design equipment with a modular parts density of 600,000 per cubic foot means dramatic space savings and makes possible an almost unbelievable number of circuits per cubic foot. Result: greater reliability through redundancy, room to improve accuracy, precision, control, sensitivity, and selectivity. RCA Micromodules are the design engineer's dream come true.



RCA Micromodules make possible equipment with a modular parts density of 600,000 per cubic foot, achievement of dramatic space savings over existing miniature electronic equipment and an amazing increase in the *number of circuit* functions per cubic foot. These advantages provide increased reliability through redundancy, room for more circuits to improve accuracy, precision, control, sensitivity.

RCA Applications Engineers are at work now converting equipment designers' circuits into developmental modules. All customers' circuits are treated in strictest confidence, of course. For some we have standard modules, for others we design circuits. And we are currently developing even more standard circuits. We sincerely believe it will be very much to your advantage to prepare your equipment designs for modularization now. Your RCA Field Representative can get you started. Call him today.



Micromodules were developed in cooperation with the U. S. Army Signal Corps. They are units in which several micro-elements are combined to perform specific circuit functions—amplifier, oscillator, or divider for example. The micro-elements are tiny ceramic wafers approximately 3/10th inch square and 1/100th inch thick, on which conducting, semiconducting, and insulating materials are fused to provide the electrical characteristics of basic electronic components such as resistors, capacitors, and transistors. The elements are interconnected and encapsulated to form Micromodules.

Also available at your local RCA Semiconductor Distributor

RADIO CORPORATION OF AMERICA

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CIRCLE 89 ON READER-SERVICE CARD

major advance in miniaturization:

SUPRAMICA® 555 commutator plates

360 rectangular contact 2-pole commutator plate of SUPRAMICA 555 ceramoplastic

on a 3 inch precision-molded plate ...up to 540 rectangular contacts!

Since 1948 . . . when Mycalex Electronics Corporation pioneered the first *precision-molded* MYCALEX® 410 glass-bonded mica, 180-contact commutator plate . . . MYCALEX switches have introduced a degree of accuracy and dependability never before approached in mechanical switching.

And now, Mycalex offers a *new* ceramoplastic commutator plate design destined to set *even higher* standards for long-life, low-noise-level multiplexing.

Typical of these new plates is the CP 427. Its specifications call for *precision-molded* SUPRAMICA 555 ceramoplastic which delivers total dimensional stability as well as superb thermal endurance (700°F.). The individual contacts of this plate have an exclusive *rectangular* form and embody tolerances within the .0005" range. They are permanently fixed in place.

An exclusive brush-holder design permits *lower pressures* on the wipers . . . gives *lower contact resistance* with a noise level of *less than 10 microvolts*. Brush bounce is eliminated and life greatly extended. MYCALEX switches using this type of design have been tested satisfactorily for over 1000 hours at 600 RPM without maintenance.

Information on complete MYCALEX switches or matched brush assemblies and plates is available.

General Offices and Plant: 127-G Clifton Blvd., Clifton, N. J.
Executive Offices: 30 Rockefeller Plaza, New York 20, N.Y.

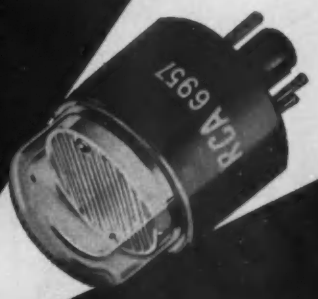
SYNTHAMICA® SUPRAMICA® MYCALEX®

MYCALEX
ELECTRONICS CORPORATION

EXCLUSIVE LICENSEE OF MYCALEX CORPORATION OF AMERICA

"See Our Newest Products, Booth 836, Instrument-Automation Show, Sept. 21-25."

All cells shown actual size

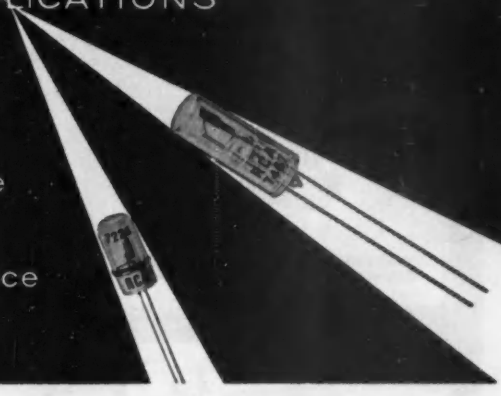


RCA

PHOTOCONDUCTIVE CELLS AND PHOTOJUNCTION CELLS

FOR INDUSTRIAL APPLICATIONS

- High Sensitivity
- Small Size
- Reliable Performance

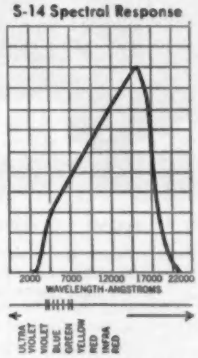


If your control problems involve a light source, look to RCA for the solution. RCA-designed Photoconductive and Photojunction Cells are manufactured under the strictest quality controls to assure dependability and long life. So for applications ranging from street-lighting control to high-speed computers, contact your RCA Field Representative for complete information about RCA Photoconductive Cells and RCA Photojunction Cells. Or for technical data on specific types, write RCA Commercial Engineering, Section I-56-Q, Harrison, N. J.

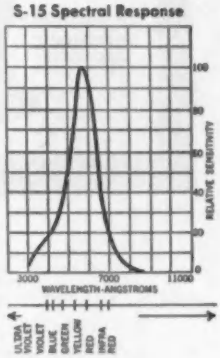
RCA Type	Description	Spectral Response	Wavelength of Max. Spectral Response	Maximum Ratings Abs.—Max. Values: Voltage Between Terminals	Power Dissipation	Ambient Temperature Range	Characteristics at 25°C: Voltage Between Terminals	Sensitivity: Radiant	Luminous	Illumination	Max. Dark Current
			angstroms	volts	mw	°C	volts	μa/μw	ma/lumen	μa/fc	μa
6957	Cadmium-sulfide, head-on photoconductive cell for street-lighting control and other light-operated relay applications.	S-15	5800	250	500	−75 to +60	50	580	1640	4000	20
7163	Compact, cadmium-sulfide, head-on photoconductive cell for street-lighting control and other light-operated relay applications.	S-15	5800	250	300	−75 to +60	50	290	820	2000	40
7223	Very tiny photojunction cell of the head-on type. Employs germanium p-n alloy junction. For computer and sound-pickup-from-film applications. Infrared sensitive.	S-14	15000	50	25	+50 Max.	2.5	0.68*	—	0.2	35
7224	Very small photojunction cell of the side-on type. Employs germanium p-n alloy junction. For sound-pickup-from-film and computer applications. Infrared sensitive.	S-14	15000	50	30	−40 to +50	45	0.52	14	0.7	35
7412	Small cadmium-sulfide, head-on photoconductive cell. For industrial light-operated relay applications.	S-15	5800	200	50	+60 Max.	12	1500	4500	300	0.1
7467	Very small, photojunction cell of the side-on type. Employs germanium p-n alloy junction. For sound-pickup-from-film and computer applications.	S-14	15000	50	30	−42 to +50	45	0.52	14	0.7	35

*μa/watt/meter²

S-14 Spectral Response



S-15 Spectral Response



Visit the RCA exhibit at the I.S.A. Conference, Chicago

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Electron Tube Division **Harrison, N. J.**

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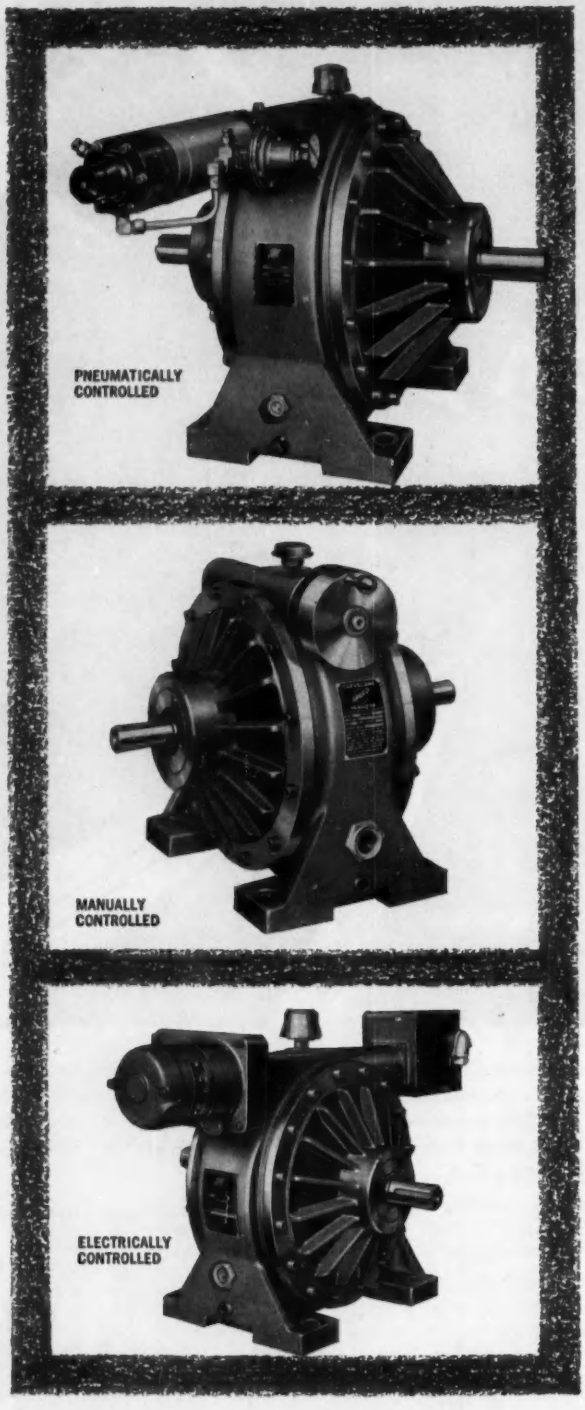


with Cleveland Speed Variators... precision control is a simple matter

Cleveland Speed Variators — mechanical traction-type variable drives with stepless speed control — provide both increase and decrease of output speed on a range up to 9:1 from a constant speed power source.

Infinitely variable speed regulation is provided with instant, smooth change by either manual, automatic, or remote control. Precise adjustments are easily made with accurate adherence to settings. Some typical examples:

For the Chemical Industry
In rubber processing seventeen variators provide necessary process flexibility when changing production from one type synthetic rubber to another.

For the Automotive Industry
Variators give accurate control of assembly line speeds to control conveyor output rates.

For the Tobacco Industry
Variators make delicate adjustments for electronic beta gage controller.

For the Steel Industry
Variators provide remote control speed change on processing line conveyor.

For the Metal Working Industry
Variators permit fast, accurate adjustment of machining speeds for metals, from magnesium to 38 Rc steel.

For the Wire Products Industry
Variators control four reels simultaneously — and without slippage.

In Ore Processing
Variators easily adjust rate of material feed to hammermill.

In Material Handling
Variators control movement of steel tubes through 176-roll annealing furnace.

HOW IT WORKS

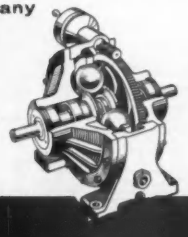
Power is transmitted from input shaft to output shaft through alloy steel driving balls which are in pressure contact with discs attached to the two shafts. Relative speeds of the shafts are adjusted by changing the positioning of the axles on which the balls rotate (see cutaway view, right).

The Cleveland Worm & Gear Company
Speed Variator Division
3260 East 80th Street, Cleveland 4, Ohio

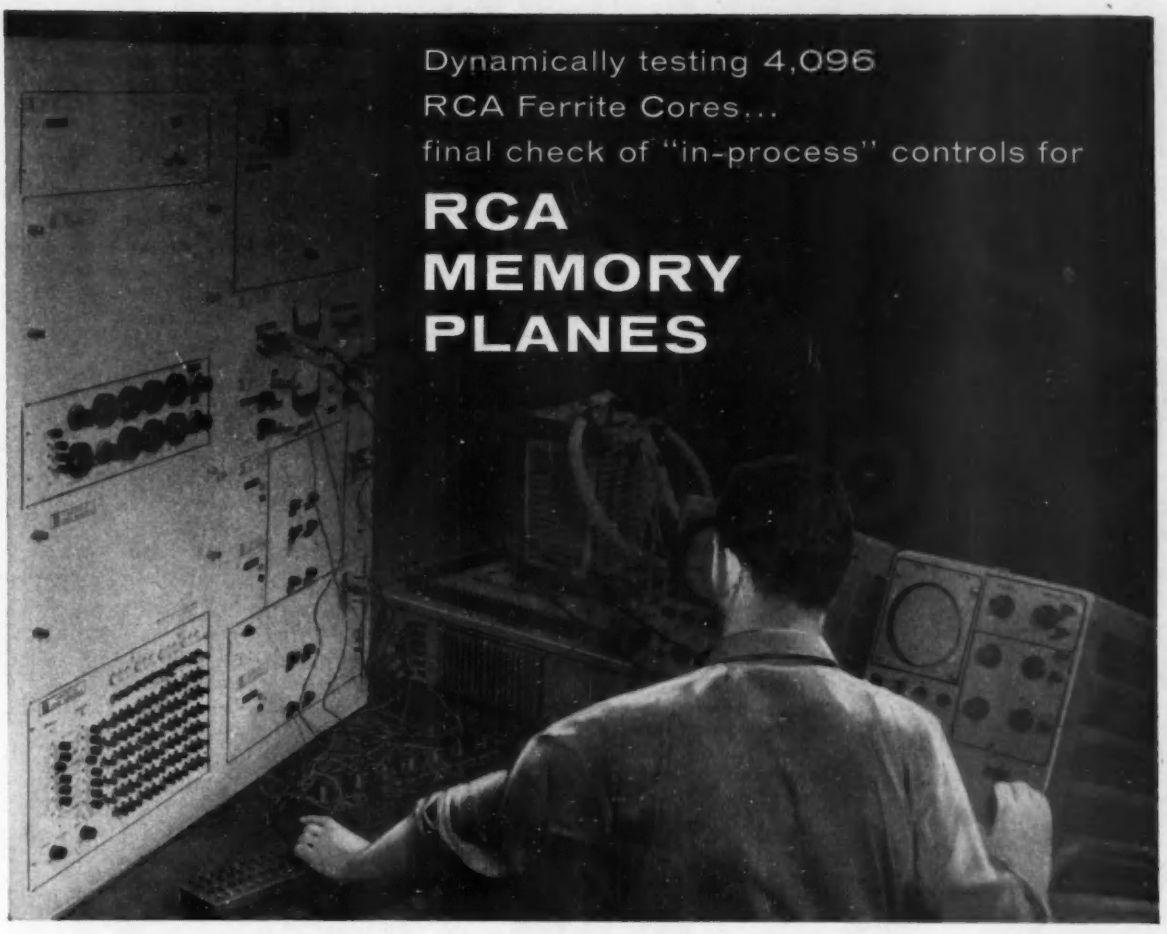
A subsidiary of
Eaton Manufacturing Company

Sales representatives in all major industrial markets.

Send for your free copy of Bulletin K-250. It gives the complete Variator control story.



CLEVELAND SPEED VARIATOR



Unique memory plane and stack tester dynamically tests every RCA core in every RCA plane while the entire stack is being driven ... assures extremely high uniformity from core to core.

This dynamic Plane and Stack Tester at RCA's Ferrite Plant in Needham Heights, Massachusetts, is one of the most versatile and efficient test apparatus of its type in use today. It evaluates each RCA coincident current type of memory plane and stack *under actual use conditions* and provides 100% testing to your rigid specifications at typical computer frequencies. During tests, two programs are run alternately in the machine: first program 1 and then program 2. Each program is capable of writing all ones, all zeros, the double checkerboard pattern and its complement, or the double complemented checkerboard. Defective cores are immediately detected and identified...cores with the highest ones or lowest zeros, or early or late peaking characteristics can also be eliminated to further assure uniformity from core to core.

This testing procedure is another example of "in-process" controls employed by RCA in every stage from the selection of raw materials to the inspection of finished product. For Ferrite Cores, Planes, and Stacks to meet your most rigid specifications, contact your local RCA Field Representative. For technical data, write RCA Commercial Engineering, Section I-56-NN, Somerville, New Jersey.

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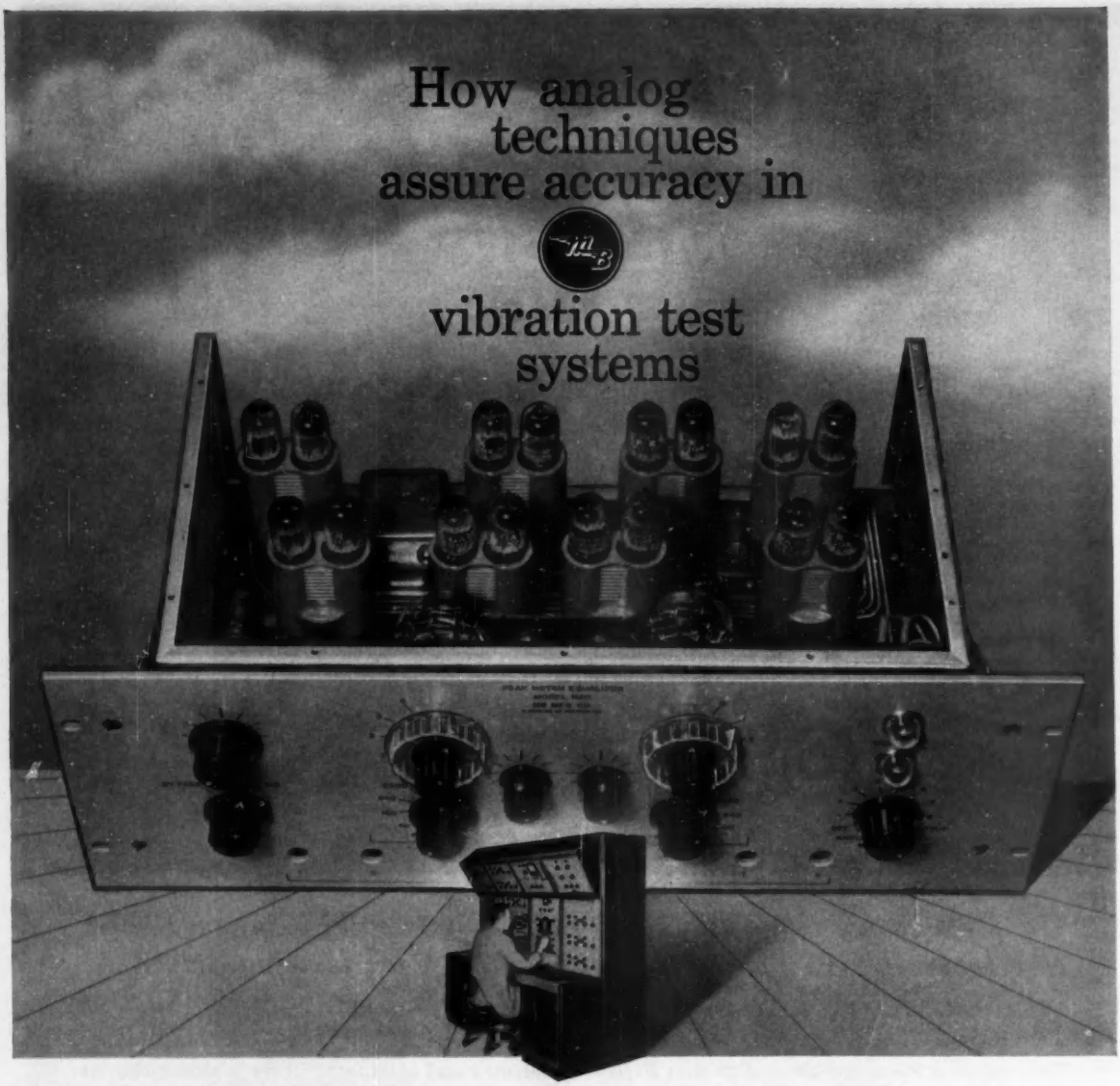


MB Electronics, manufacturer of complete complex motion testing systems, uses modern analog computor techniques to reproduce actual vibrational environments met in the operation of aircraft and missiles.

The MB Model T88 Complex Motion Console, which puts all the system controls within easy reach of a single operator, utilizes 10 Peak & Notch Equalizers — each containing 8 K2-W analog DC amplifiers by Philbrick. The equalizers are the key to test system accuracy. They adjust to the exact inverse electrical equivalence of the mechanical system resonance, and automatically provide the mass offset required for any table loading condition by assuring a flat frequency response identical to that of the input voltage.

GEORGE A. **PHILBRICK** RESEARCHES, INC.
285 COLUMBUS AVE., BOSTON 16, MASS. TEL. COMMONWEALTH 6-5375

This is a special application, true. But it may provide the spark of an idea as to how you can use analog techniques — and efficient Philbrick plug-ins — to your advantage. Write for freely given opinions on your particular problem.

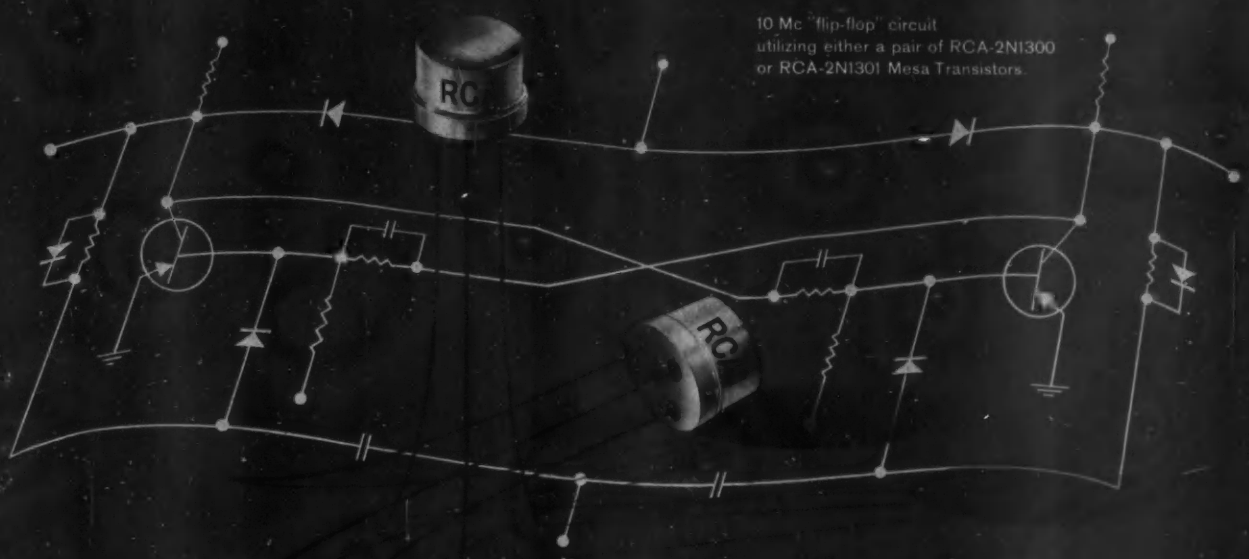
The analog way is the model way

MODEL K2-W — an efficient foolproof high gain operational unit for all feedback computations, fast and slow. A number of special varieties are also in quantity production. **$24.00**

MODEL K2-P — offers long-term, sub millivolt stability, by itself or with the K2-W. High impedance chopper-modulated input. Filtered output to drive balancing grid or follower. **$60.00**

MODEL K2-WJ — If the rigors of your application deserve a JAN-ized form of K2-W, the K2-WJ is now available. 5751 tubes and MIL standard components are used throughout at no increase in size. **$58.00**

ALL K2 PLUG-INS RUN ON PLUS AND MINUS 300 VDC AND 6.3 VAC. SOCKET WIRING IS SIMPLE AND STANDARDIZED.



10 Mc "flip-flop" circuit utilizing either a pair of RCA-2N1300 or RCA-2N1301 Mesa Transistors.

RCA-2N1300 and 2N1301

LOW-COST MESA
COMPUTER TRANSISTORS

Now in quantity production . . . and available!

RCA-2N1300 and 2N1301 Germanium P-N-P Mesa Transistors offer these 10 major benefits to designers of switching circuits. And they're ready for you now!

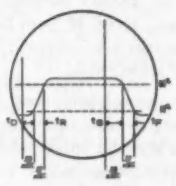
- **rugged Mesa structure—permits extremely small base width to insure top performance at high frequencies**
- **fast switching times with low values of base input current—made possible by high frequency response and low total stored charge**
- **high current gain—permits high fan-out ratios (number of paralleled similar circuits per driver-stage output)**
- **high breakdown voltage and punch-through voltage ratings—the result of the diffusion process**
- **high power dissipation—150 milliwatts at 25°C—aids in the design of reliable circuits**
- **high current ratings—improve overall system speed**
- **rugged overall design—units have unusual capabilities to withstand severe drop tests and electrical overloads**
- **electrical uniformity—a result of the diffused-junction process used by RCA in the manufacture of Mesa Transistors**
- **especially well suited for use at pulse repetition rates up to 20 Mc**
- **exceptionally well suited to applications in saturation-type switching circuits**

Information on RCA-2N1300 and 2N1301 Low-Cost Mesa Transistors is available from your RCA Field Representative. For technical data, write RCA Commercial Engineering, Section I-56-NN, Somerville, N. J.

RCA TYPE	Maximum Ratings* Absolute-Maximum Values						Characteristics: Common-Emitter Circuit, Base Input Ambient Temperature of 25° C		
	Collector-to-Base Volts	Emitter-to-Base Volts	Collector Milli-amperes	Transistor Dissipation—mw			Minimum DC Current Gain		Gain Bandwidth Product** Mc
				at 25°C	at 55°C	at 71°C	at collector ma = −10	at collector ma = −40	
2N1300	−13	−1	−100	150	75	35	30	—	40
2N1301	−13	−4	−100	150	75	35	30	40	60

*Maximum collector-to-emitter voltage rating = −12 volts

** For collector ma = −10 and collector-to-emitter volts = −3.



Oscilloscope wave form shows typical delay, rise, storage, and fall times achieved with 10-ma inverter circuit utilizing the RCA-2N1301 MESA TRANSISTOR.

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SEMICONDUCTOR AND MATERIALS DIVISION • SOMERVILLE, N. J.

ALSO AVAILABLE THROUGH YOUR LOCAL RCA SEMICONDUCTOR DISTRIBUTOR.

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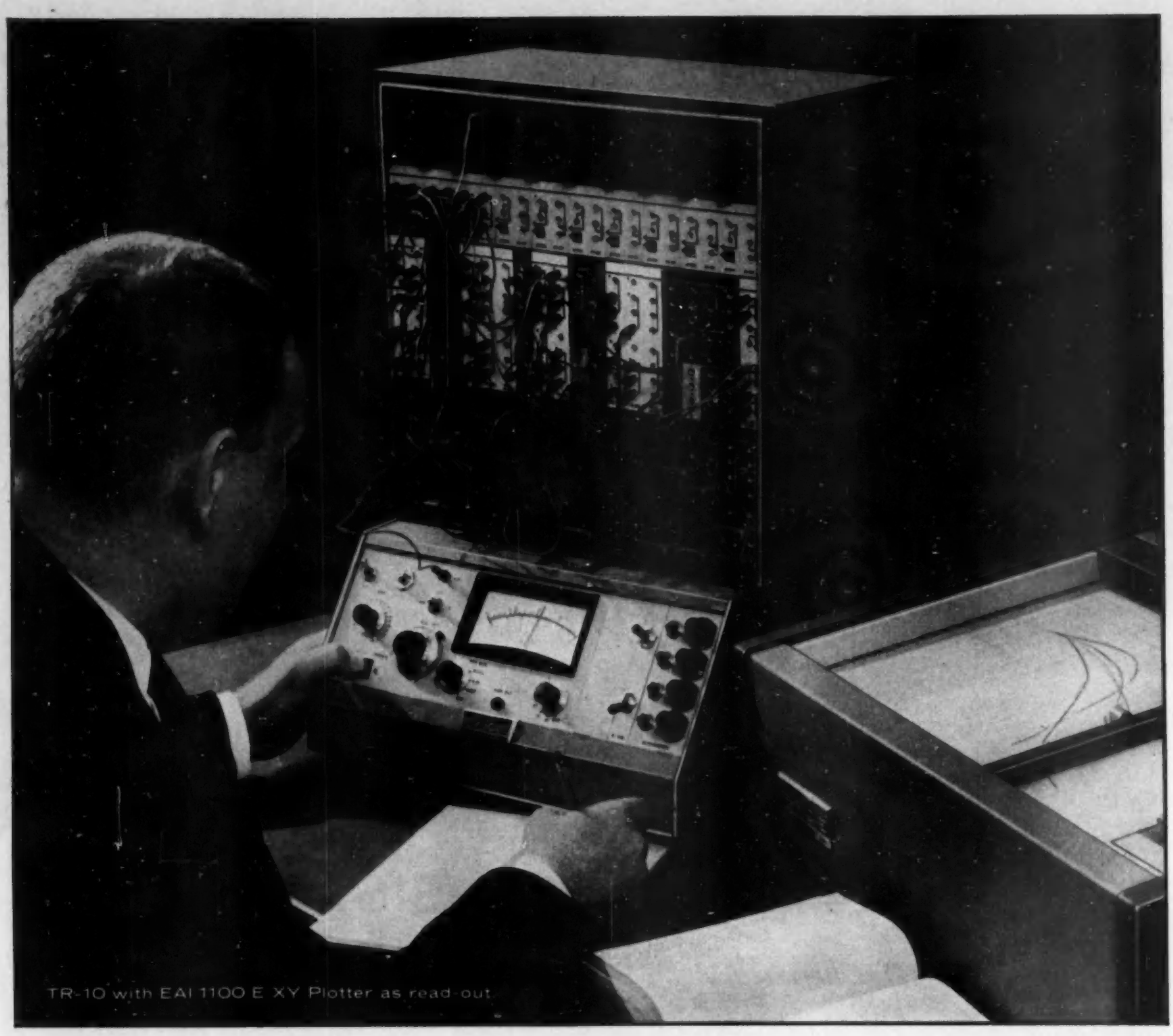


TR-10 with EAI 1100 E XY Plotter as read-out

THE *FIRST* ALL TRANSISTORIZED ANALOG COMPUTER

—basic model less than $4000

PACE® TR-10 Eliminates Drudgery—Gives New Insight Into Engineering Problems

This compact unit, 15" x 16" by 24" high, is powered by 115 volts AC and can provide day-in day-out instant solution of your most vexing engineering problems. Even if you have never seen a computer before, you can learn to operate the TR-10 as easily as you learned to use a slide rule.

Simply turn a dial to feed in design parameters, and the computer provides an instant by instant, dynamic picture of the effect of each change. You can study the inter-related effects of heat, pressure, flow, vibration, torque or any variable, and visually compare one with the other. Engineering data comes alive – insight into how new designs will work is obtained easier, faster.

Because of its minimum size and low price, the TR-10 can become your own personal analog computer. You gain first-hand experience with the power of analog techniques, and convert more of your time to *creative engineering*. New ideas that were too costly to try before are now practical.

You can design virtually to perfection and have a permanent, visual record of performance before building pilot models or prototypes. As a result, "cut and try" expense is reduced.

The same quality workmanship and design that has made Electronic Associates the world's leading producer of precision general purpose analog computers will be found in this new unit. Accuracy to ±.1 per cent. Modular construction allows you to select varying quantities of the following computing functions: summation, integration, multiplication or division, function generation, parameter adjustment, logical comparison.

For complete engineering data, write for Bulletin TR-10-d.

EAI ELECTRONIC ASSOCIATES, INC.
Long Branch, New Jersey

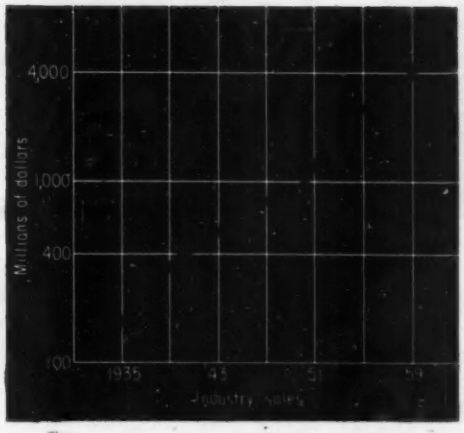
Through the Rearview Mirror

Clippings pinpoint five years of growth and change

In the control field, tomorrow has a habit of arriving much sooner than expected. A visionary development, for which a control engineer's more orthodox colleagues publicly give him five years (and privately give him a lifetime or write him off altogether), becomes a requirement for immediate application within two years or less. While continuing to devote most of our attention to the road right ahead, and to as much of it as we can see far ahead, it is sometimes rewarding to glance back through the rearview mirror at some of these developments that have occurred "before their time". These developments are basic influences on the research and development, design, and improvements that will occur in the next five years.

Before

Goods and services furnished by makers of instrumentation and control were valued at $2 billion in 1954 and were increasing at the rate of two or three times in seven years. The equipment was, and still is, a mixture of electrical, electronic, pneumatic, hydraulic, and optical control system components. Because of this inter-disciplinary mix and because of similar diversity in the backgrounds of the engineers practicing in the field, none of the well-established technical societies could claim the entire area.



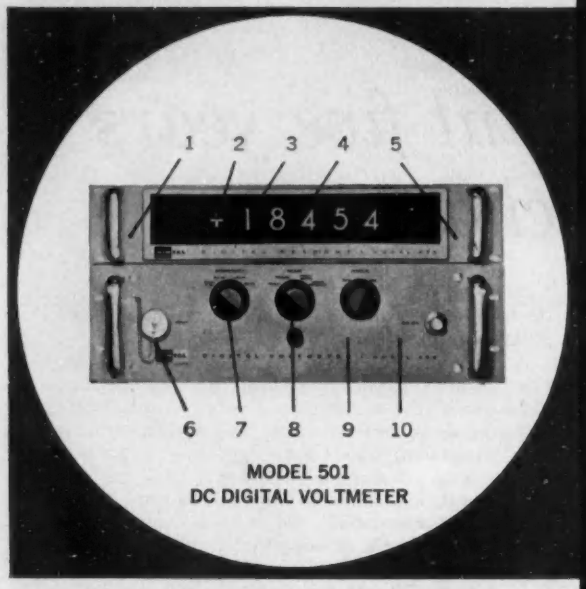
A control field did exist, but it consisted of elements that had not yet generally been linked. Industrial control, so-called by manufacturers who furnished drives and controls for heavy industry, had developed its own lore, equipment, and terminology over a period of twenty years. Industrial control was part and parcel of electrical, hydraulic, and pneumatic drive systems. Process instrumentation and control had developed quite independently of industrial control, but over a longer period of time. It had equipment, practices, and a language that it didn't share with industrial control. Aeronautical and weapons control blossomed during World War II and continued in full bloom after the war. While some of its equipment and philosophy was originally based on those of its industrial and process counterparts, it, too, grew independently and quickly became a third element of the control field, with its own unified language, advanced components, and highly organized methods of system analysis and synthesis. Five years ago this organized approach was just beginning to penetrate industrial control and process control.

The largest common denominators among the three elements of the field were: a creative drive to make operations automatic and consequently improve their performance, cross-disciplined mixtures of equipment, and the emergence of a general technique of control systems engineering. The stage was set for a steady technical development of the field and an accompanying slow but sure integration.

Enter labor leaders and politicians

There was some public interest in the "gee whiz" aspects of self-correcting systems, but it was merely a form of polite curiosity. However, noting the effect on productivity and needing an issue, labor unions became embroiled. Claiming that the productivity gains were all at the expense of the labor force, they

HERE'S WHY CALCULATING ENGINEERS USE KIN TEL DIGITAL VOLTMETERS

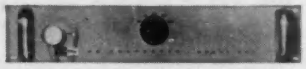


MODEL 501
DC DIGITAL VOLTMETER

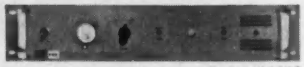
1. **Single-Plane Readout**...no superimposed outlines of "off" digits...readout lamps have ten times longer life.
2. **Automatic Polarity Indication**...no lead switching.
3. **Ten Times Greater Resolution** at decade voltage points than other 4-digit voltmeters. A unique extra fifth digit in the left decade indicates "0" or "1" to provide 100% over-ranging.
4. **Automatic Ranging**...decimal point is automatically positioned for maximum resolution and accuracy.
5. **Remote Readout Mounting**...no electronic circuitry in readout allows easy remote mounting.
6. **Floating Input**...input may be floated above or below chassis ground...10 megohms input impedance...input connectors on front and rear.
7. **Adjustable Sensitivity**...control permits decreasing sensitivity to allow reading of noisy signals...greatly increases instrument usefulness.
8. **Built-in Printer Drive** for parallel input printers...control permits either automatic operation when voltmeter reaches null, or remote operation by external contact closure.
9. **Reliability**...transistor drive circuits provide "cushioned" DC drive for stepping switches for long, trouble-free operation.
10. **Accuracy**...measures DC from ±0.0001 to ±1000.0 volts...continuous, automatic calibration against internal standard cell provides 0.01% ±1 digit (of reading) DC accuracy.

Price: $2995

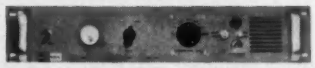
These let you measure AC, increase sensitivity, measure ratios, scan multiple inputs



AC CONVERTER **Price: $850**
The Model 452 AC converter can be added to the basic 501 DC digital voltmeter to permit 4-digit measurement of 0.001 to 999.9 volts AC, RMS, 30 to 10,000 cps. Accuracy is 0.2% of full scale and ranging is manual (auto-ranging models are available).



DC PREAMPLIFIER **Price: $1475**
The Model 459 differential DC preamplifier has a gain of —100 which extends the DC sensitivity of KIN TEL digital voltmeters to 1 microvolt. Overall system accuracy when the 459 is used with a digital voltmeter is 0.15% ±5 microvolts. Input resistance is greater than 5 megohms, and input and output circuits are completely floating and isolated from each other and chassis ground. Common mode rejection is 180 db for DC and 130 db for 60 cps with up to 1000 ohms input unbalance. Input can be floated up to ±250 volts.



AC-DC PREAMPLIFIER **Price: $1225**
The Model 458 is a single-ended preamplifier with a gain of —100 which extends the sensitivity of KIN TEL digital voltmeters to 1 microvolt DC, and 10 microvolts AC from 30 to 2000 cps. Overall system accuracy when the 458 is used with a digital voltmeter is 0.1% ±2 microvolts for DC, and 0.25% of full scale for AC.

DVM & RATIOMETER **Price: $3835**
The Model 507A measures both DC voltages from ±0.0001 to ±1000.0 volts and DC/DC ratios from .0001:1 to 999.9:1. Ranging is automatic and accuracy is 0.01% ±1 digit both for ratios and voltage. Any external reference between 1 and 100 volts may be used for ratio measurements.

INPUT SCANNER
The Model 453M master scanner automatically or manually scans up to 400 1-wire, 200 2-wire, or 100 4-wire inputs. Addition of a slave scanner (453S) permits scanning up to 1000 data points.

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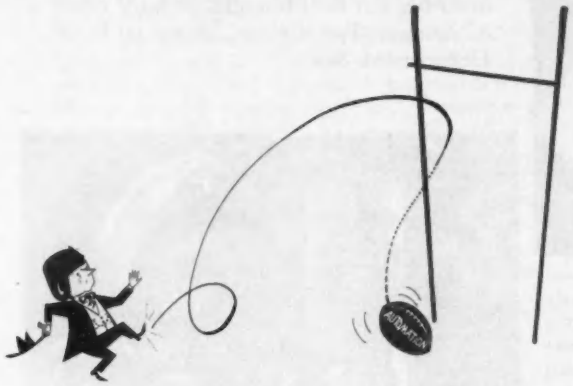
overlooked the other factors of the productivity equation that control was reducing—costs of materials and energy. Correct or not, they got tremendous public attention and passed the ball to politicians. Congressional investigations, special Sunday supplements, TV programs, and flocks of two-week experts mushroomed. Automation, as it was tagged, became public property. Almost overnight, public interest changed from polite curiosity to vital concern.

Business managements became automation-conscious. Automation became a rating, loosely describing the



extent of mechanization rather than a function of the control field, such as instrumentation or actuation. Confusion and some misguided effort resulted, but we can now say that the general effect was helpful. For the intense public interest and the awareness of management created a demand for instrumentation and control, the tools of improved performance. The control engineer became, and has remained, the key figure in successful automation programs. Gathering in "recruits" three times as rapidly as had been expected before automation became public property, the control field was ready to boom by 1954. And boom it has during the five years that have now elapsed. A profession has emerged. Practical system engineering techniques have evolved. New products have spewed forth, and applications have spread to just about every conceivable operation.

New applications
New techniques
New products

Imagination has uncovered uncounted opportunities for instrumentation and control. Adequate new products have usually swarmed to compete for applications that have been limited only by knowledge and financial return. Applications have spanned freight yard classification, numerically controlled metalworking, banking, inspection, missile checkout, anesthesia, flight-testing, warehousing, chemical pilot plants, pipeline custody transfer, generation and distribution of kilowatts, mail sorting, automobile guidance, air traffic, and order picking, to name a few. Throughout this diversity some approaches and products have been applied so frequently that they stand out as principal trends: analysis instrumentation and continuous testers, digital techniques, computing control, solid-state devices, program control, and test.

Analysis instrumentation and continuous testers

New instruments for measurement of composition and quality showed promise for improving performance by a degree never realized before, but there were still bridges to cross on the way to perfecting them for plant application. *"Out in the plant, continuous analyzers are opening the way to instantaneous control of stream composition. Even with mechanized laboratory analysis the measurement lag is formidable, particularly in sampling. The obvious solution would be to move the laboratory to the problem, that is, to tie the infrared spectrometer directly into the process stream, where it can produce continuous and instantaneous data."*—October 1954, p. 42.

Digital techniques

Hectic activity was about to break loose in the use of digital equipment in information systems and control systems. The introduction to a dual series of articles listed what the control engineer needed to know about their basics and their applications:

- Digital Basics . . . *"the theory of numbers, logical design, arithmetic elements, storage, and basic programming."*
- Digital Applications . . . *the use of digital equipment in "solving scientific problems, handling business data, and controlling a process."*

—October 1955, p. 69.

The techniques were based on *"electronic pulses, the vital heartbeat in a wide variety of control, timing, and sequencing devices such as computers, feedback control systems, telemetering, and electronic test apparatus."*—July 1955, pp. 56-64.

Very early, in the swing to digital systems, *"digits linked to feedback took major strides in Vermont, where a digitally directed, hydraulic servo-positioned*

KOLLMORGEN Remote Viewing Systems...
used in most atomic installations

Photo courtesy Phillips Petroleum Company

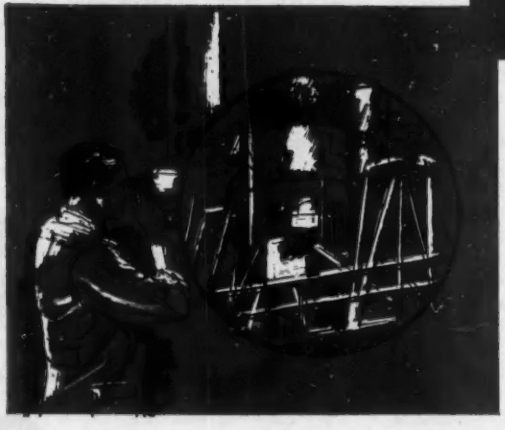
A Phillips Petroleum Company technician observes radioactive metallurgical specimens through a Kollmorgen Hot Cell Periscope installed at the Materials Testing Reactor Hot Cell, National Reactor Testing Station. The periscope helps determine characteristics such as tensile and impact strength, hardness, weight and density changes. Macrophotography of specimens is also performed through the periscope.

Radioactivity, caustic fumes, blast forces, inaccessibility and other adverse conditions hamper observation and inspection. To overcome these conditions, more and more installations in a widening range of industries are using Kollmorgen remote viewing instruments. Kollmorgen specializes in the design and manufacture of instruments and systems for detailed observation under difficult or apparently impossible circumstances. Most of these devices can be readily adapted to photography or television.

We have recently prepared a twenty-four page illustrated brochure which describes our facilities and primary fields of interest. For a copy, please write to Department 219.

The Nautilus and her sister ships of the Atomic Fleet, like most other U.S. submarines, are equipped with Kollmorgen periscopes. These instruments require highly precise optical, mechanical and electronic components.

and from Cape Canaveral to the



Kollmorgen Bunkerscopes are used at Cape Canaveral for observation of missile launching operations and static tests. Bunkerscopes allow detailed observation from a considerable distance with no danger to the operator. Images appear in bright, clear, natural color. There are no maintenance costs with these Bunkerscope operations.

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turret lathe was put through its paces before its Chicago unveiling Sept. 6 and in Montreal, where perhaps the most complete automatic processing plant in the world was speedily nearing its 'onstream' day. Its 126-ft graphic panel and its all-electronic control loops were [tied in with] its digital data processing system, a noteworthy 'first'."—September 1955, pp. 22-23.

Computing-control

The improvement in digital techniques made computers more compact, more reliable, within reach in cost, and—available. Thus was made possible computing-control which . . .

". . . has one over-riding justification—improved performance. It will bring about better performance of machinery, plants, and weapons, in terms of better stability of operation, quality of product, production rate, efficiency, or yield.

". . . compares the interacting conditions and behavior of the equipment to which it is applied, and from these combinations and comparisons, it makes optimum changes in energy and material supplies or in subsystem commands.

". . . is the center of a widening circle of control techniques and products.

"Further advances require—analysis, to determine the dynamic and static relationships which the computing-controller must know and invention, of instruments for direct measurement of performance where inferential measurements and computations prove inadequate."—September 1957, p. 126.

During the two years that have elapsed, the effects of computing-control on developments in measurement have become much clearer. Continuous gages, continuous inspectors, analysis instruments, and data analyzers have become the critical measuring components. Those primary measuring elements that keep track of inventory (e.g., flow rate, weight, level, width) have become more critical to computing-control than have the environmental measuring elements (e.g., temperature and pressure).

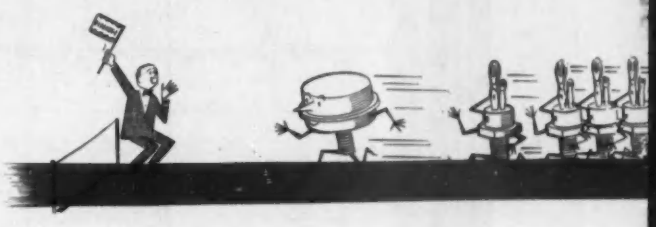
Solid-State devices

And then along came transistors. First hurdle was convincing potential users of their worth in the face of disparagement from vacuum tube proponents. Debates probed the issue. One such debate, held at the Electronic Components Conference in Los Angeles, May 26-27, 1955, brought forth this quote in favor of transistors, *"the electronic tube is a monstrous and improbable device that burns out quickly."* In rebuttal, *"transistors are like a baby that has just learned to say goo."*—August 1955, p. 18.

Transistors have long since passed the controversial stage and have been joined in acceptance by solid-state thyratrons and improved magnetic amplifiers. *"In control circuitry, power transistors have been called on to handle either of two functions: modulate power or switch a load."* Their power-handling capacity, at first much too low for important industrial applications, has increased many times. *"Only two years ago, transistor power was rated in milliwatts; today, one power transistor can switch up to 1,200 watts."*

"Into this picture the solid-state thyratron burst in November 1957. Many of its applications turned out to be those already serviced by power transistors. But . . . it [claimed] *three advantages over the power transistor: higher power rating, faster operation, and easier protection."*—April 1959, pp. 79-81.

Static switching for industrial control, introduced in mid-1955, had its ups and downs. Uses were controversial, but *"whether controlling a machine tool, a materials handling system, or a flow process, industrial*



control engineers [could] *not afford to overlook the possibilities of increased reliability, higher operating speeds, and reduced maintenance and downtime. Thus far industrial static-switching systems have been called on primarily for basic logic decisions and only infrequently for counting and information storage."*—May 1957, pp. 67-68.

In January 1959, p. 63, the editors foresaw *"a year of decision for static switching. When these devices were first introduced, their manufacturers expected that machine tool builders would be their biggest market. But the high cost of static control, the collapse of machine tool sales in 1958, and* [a postponement of Detroit's production race] *practically enervated the market. In 1959, static controls will come into their own in: steel mills, blast furnaces, and automatic warehousing."*

Program Controllers . . .

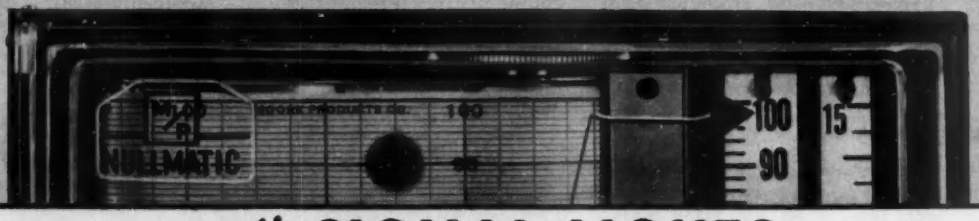
". . . set the pulsebeat of industry. Somewhere in every control system there is an element through which commands are introduced. This element establishes the cycle of operations (the routine, the program) that the system is to follow or, if the system regulates, sets its operating range.

"Scores of applications in all industry classifications —material processing, heavy machinery, aircraft and missile—[have] *brought into dramatic focus the 'pro-*

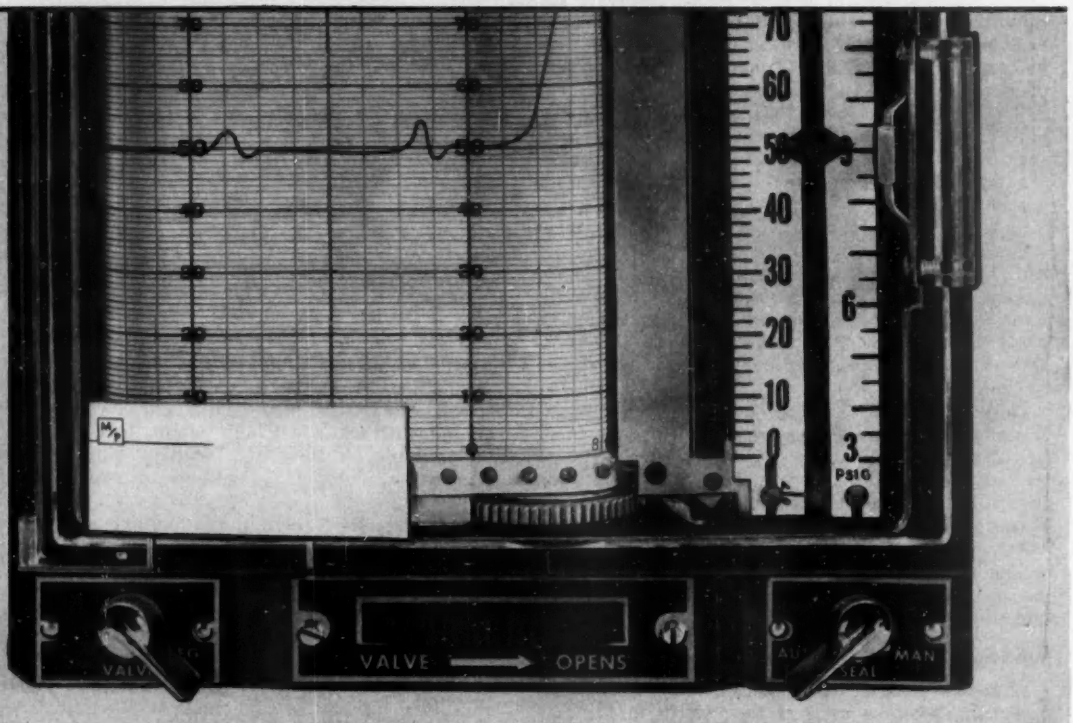
We did it for the plant operators . . .

We're sure they will like this

NEW M/P RECORDING CONTROLLER



with SIGNAL LIGHTS



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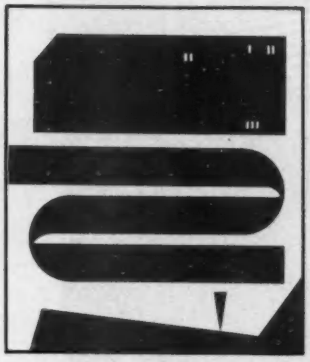
gram-control-content' of new systems: line-programmed flame cutter, tape-controlled diffractometer, blooming-mill screwdown, heat runs to simulate missile re-entry into the earth's atmosphere, treatment of acid wastes, lathe, circuit analyzer, dyeing systems for textiles, continuity checker, mechanical arm, and feed mixing.



"Fastest expanding area of program control is the application of command information recorded on curve followers, punched cards, punched tape, and magnetic tape as input media." — September 1958, pp. 113-117.

System engineering techniques evolve

"Intuition fails—system analysis bails" succinctly states why transient analysis, switching theory, and statistical analysis techniques have come to the fore. From an International Symposium on the Theory of Switching, sponsored by the Computation Laboratory at Harvard University, a conferee reported, "Before World War II the intuition of the engineer was sufficient to enable him to devise a suitable [switching] net for whatever purpose was required. He would have been the last to expect that Boolean algebra would be useful in simplifying his problem. But [switching] control circuits are becoming [so] complicated that intuition fails."—June 1957, p. 34.

Statistical techniques proved effective in evaluating test data and representing relations between man and machine* and in examining the quality of control**.

*"While the disturbance-response technique has had considerable success, it has two practical drawbacks: it usually disturbs the system enough to upset its equilibrium. This can mean off-quality product in a plant or poor performance in a [servo]; variations caused by effects other than the one under study may obscure the required information. For these reasons investigators have studied ways to extract the needed information without disturbance."—June 1955, p. 50.

**"Calculation of standard deviation and the preparation of distribution charts analyzes variations. It [provides] a yardstick of improvement and helps in determining [system] economics."—August 1958, p. 71.

More challenging work

As his partiality for dynamic analysis had made design of feedback mechanisms pretty much routine, midway through the five years the control engineer shifted his attention to more challenging topics—energy conversion, information systems, and adaptive control.

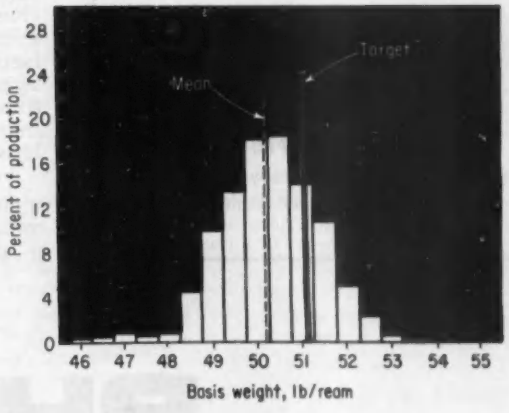
Of energy conversion, an editorial advised, "A control system is a power modulator [as well as an information handler]. Impossible demands on its power source can completely frustrate the hardware-transformation of a system designed by the message-handling approach. Relationships between power and fidelity can be established. Find the energy-transforms of a system and you can design it for adequate continuous and standby power."—November 1954, p. 21.

Of information systems, another cautioned, "Even if collected by the excess capability of an otherwise inexpensive primary sensor, data should not be processed to some more easily used form unless it is truly used [for control decisions]. Data used for control is information. Data not used is waste. 'More bits per dollar' and 'more data per dollar' are catch phrases with big holes in their logic. More used data per dollar is the realistic approach to economically sound control systems."—October 1958, p. 67.

Of adaptive control, a report on a state-of-the-art symposium at Wright Air Development Center said, "Hottest subject in aircraft flight control today is adaptive control. Dr. John Aseltine has offered three criteria for systems with an 'adaptive point of view'. There must be: a measure of system performance, a means of converting performance into a number, and a means of using this number to change the system."—March 1959, p. 22.

Economics catches control engineer

The recession brought to a peak the importance of economic analysis, a type of analysis practiced too seldom in the control field. An editorial explained why



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for tuner, video IF, sound IF

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Special MADTs*
(with revolutionary Philco cathode ray tube) for display circuits

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Philco Micro Alloy Diffused-base Transistors (MADT*) for the tuner and IF stages are products of Philco's famous FAT Lines (Fast Automatic Transfer) . . . the first automatic transistor production lines in the world. They are the *only* transistors manufactured by mass production methods to meet the exacting standards of performance, uniformity and economy to make transistorized television a practical reality. Their excellent high frequency capabilities provide sensitivity and low noise performance comparable with conventional vacuum tube receivers.

This is another example of Philco's leadership in Transistor engineering and production. To meet *your* transistor requirements, consult Philco first. *For complete information, write Dept.CE-959.*

**Trademark Philco Corp. for Micro Alloy Diffused-base Transistor*

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economic analysis had to be added to the available system engineering techniques.

"Overwhelming emphasis has been placed on solving the technical, rather than economic, problems of measurement and control. The control engineer has been conditioned by demands for increased yield—measured in terms of industrial productivity or weapons kill—to apply measurement and control equipment to improve physical performance. The performance indices were dynamics, accuracy, operating speed, capacity, reliability, safety, and uniformity.

"Now the control engineer is pressed to numerically evaluate economic performance because industry has shifted its emphasis from productivity to economy. He will be hard pressed until the current economic decline reverses under the stimulus of defense spending, new orders to replenish depleted inventories, and revitalized plans for capital investment."—March 1958, p. 79.

A profession emerges . . .

. . . through national technical societies

"All over the country engineers have been asking us whether a society of control engineers ought not to be organized. Our answer is: not now. Existing societies are beginning to recognize and meet the professional needs of control engineers." [In March 1955, the new Professional Group on Automatic Control of the IRE held its first technical conference.]

"We must pull together the related professional groups of all the existing societies . . . and not now abandon the unifying influence of control engineering."—March 1955, p. 41.

. . . through an international group

"Because of the need for international conferences, representatives of 18 countries on both sides of the Iron Curtain adopted a resolution at Heidelberg on September 27. It favored the founding of an international federation of automatic control with these objectives: 1) facilitate the interchange of information in automatic control and promote progress in this field; 2) organize international congresses on automatic control."—December 1956, p. 33 .

"The international highlight in automatic control in 1960 will be the first International Federation on Automatic Control (IFAC) Congress, scheduled for June."

American Automatic Control Council, organized in March 1957, represents affiliated societies to IFAC and has set up a joint-society steering committee for pooled annual meetings on control in the U. S. A. "Sponsorship will rotate among the affiliated societies according to this schedule: IRE, 1959, Dallas; ASME, 1960, Cambridge; ISA, 1961, Philadelphia; AIEE, 1962; and AIChE, 1963."—March 1959, p. 48.

. . . through books, papers, and articles

"We don't sponsor a 'book-of-the-month' plan for automatic control—not yet, anyway. We do, however, want to help the control engineer build an up-to-date library. So we've asked Prof. T. J. Higgins to write a series of three articles, beginning in this issue, that will evaluate useful books on industrial and process control, servomechanisms, and computers."—November 1954, p. 4.

"Of consequential literature on control, I now have on hand some 9,000 references and 5,000 reprints gathered over the past decade. At present, about 1,000 new pertinent titles appear regularly, and the rate of publication is increasing. My bibliography for the Moscow conference will run to 5,000 classified items."—communication from T. J. Higgins, June 23, 1959.

. . . through special short-courses

"Summer courses will, this year, offer control engineers plenty of opportunity to pursue their specialties at Case Institute, Cornell, Illinois Institute of Technology, MIT, Michigan, Northwestern, Oklahoma, Wayne, and West Virginia. Topics: process control, fundamentals of feedback control systems, analog-digital conversion techniques, digital computer application engineering, data processing in business and industry, and gas measurement."—May 1957, p. 29.

. . . through trade associations

"NEMA systems section gets underway. Task forces start meeting to develop standards for industrial automatic systems. At its first meeting in January it set up a General Engineering Committee to establish standards for definition, compatability of system components, and system performance . . . Scope of activities includes program control, data logging, data processing, computing control, and automatic warehousing."—February 1959, p. 28; July 1959, pp. 30-79.

W. E. Vannah

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to your Control Problem

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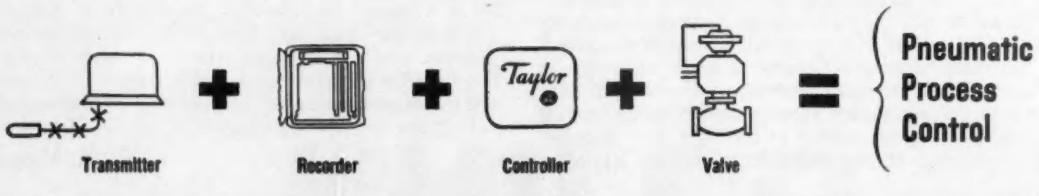
PNEUMATIC SYSTEMS



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Drawn from our Application Engineering, Design Engineering, and Sales Departments, these men have behind them many years of experience in instrumentation throughout the processing industries. They are responsible for the enviable reputation that Taylor is earning around the world . . . a reputation for vision and ingenuity in working out successful solutions to tricky control problems.

You will see the most advanced models in both pneumatic and electronic instrumentation on display. Many of them will be demonstrated as working models.

Here is an opportunity to tap a storehouse of information on all aspects of process control. Consultation with these men will cost you nothing—it may save you much.

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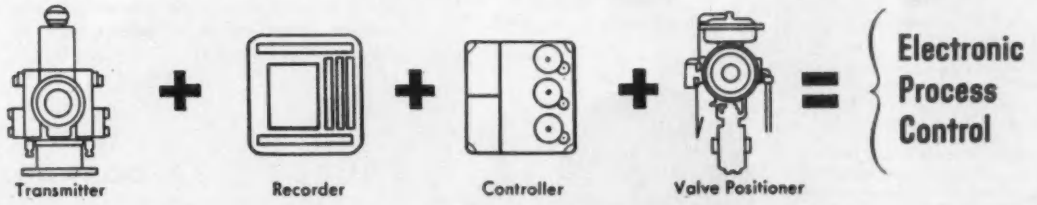
Taylor Instruments **MEAN ACCURACY FIRST**

ELECTRONIC SYSTEMS



WANTED

An ultra reliable static component to control high power AC circuits!

A missile misfires at Cape Canaveral. An automated production line jerks to a stop. An airliner "bellies in" with its landing gear up. A stalled car snarls up rush-hour traffic. And a crisis develops on the home-front when a washing machine conks out.

Common everyday incidents like these may seem unrelated to most people—yet actually, in a great majority of cases, they can all be traced to a single source of trouble:

Failure on the part of some switching device to open or close an electrical circuit.

In view of the increasing frequency of such costly failures, it is now generally conceded that components based upon present day control concepts are simply unable to keep pace with the advancing needs of modern industrial technology. For example:

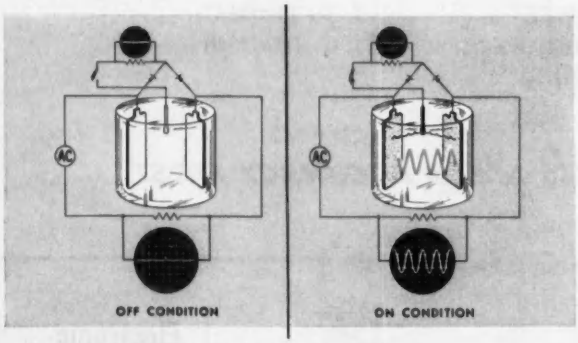
Electromagnetic-mechanical devices will carry substantial loads—but their springs, linkages and contacts are inherently susceptible to wear, malfunctioning and failure.

Announcing a basic new electrochemical phenomenon/the first non-magnetic

Ovitron *electro surface impedance*

Now, from advanced research in electrochemistry and neurophysiology, comes an amazing new type of static control. One which is inherently capable of switching and modulating high wattage ac circuits without moving parts or magnetic coils. And one so simple in concept and sound in principle that its basic phenomenon of "control through electro-ionic surface impedance changes" can readily be applied with unprecedented reliability to a broad range of commercial, industrial and military applications.

In essence, these new Ovitron static control units consist of a small, rugged permanently sealed cell containing two semiconductive load-connected electrodes *and a grid control element*—all three of which are immersed in an electrolytic compound. Obviously, in this OFF condition, load current cannot pass through the unit. Upon application of a small energy stimulus introduced through the grid element, however, a dynamic new electrochemical phenomenon occurs—*instantaneously and without fail!*



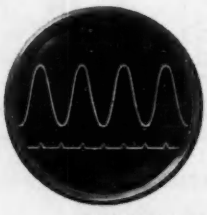
The semi-permeable surfaces of the two load electrodes become permeable to certain ions and are immediately changed from their non-conductive state to a conductive state—thus allowing large amounts of alternating current to flow via electro-ionic conduction from one electrode to the other through the medium of the electrolyte. Moreover, in operation, this high wattage ac load is controlled entirely by the small energy stimulus—and in a manner which permits either switching or modulation to take place without harmful effects on the device.

When the small control signal is removed from the grid element—or when another signal of opposite polarity is applied—the surfaces of the two load-carrying electrodes are restored at once to their original non-conductive state, thereby effectively blocking the flow of current.

A 20-page brochure contains a detailed technical description of these principles—lists inherent advantages and operating characteristics—gives status of present product development program. Want a copy?

No moving parts, no magnetic coils. No wear, disintegration or loss of efficiency with age, environment or continuous use.

At right: Ovitron's undistorted sine wave output and pulsating dc control. Ratio can be varied as required to suit application.



Ovitron **CORPORATION**

14830 Schaefer Highway • Detroit 27, Michigan

CIRCLE 101 ON READER-SERVICE CARD

Magnetic amplifiers generally offer longer life expectancy—but they are much too large, heavy and expensive for a great many applications. Vacuum tubes can be used as switches—but only for low power direct current applications, and only where their fragility and limited filament life are acceptable shortcomings. Transistors are also low power dc devices—require involved circuitry and the use of multiple units for ac applications—and are inherently restricted by temperature sensitivity and current carrying limitations, particularly when modulated. And controlled rectifiers—an extension of the transistor art—face many of the same problems. Although they can carry larger loads, they still must be used in pairs to control ac—and they're also affected by temperature. Moreover, they have a distorted sine wave output, cannot be modulated, and are difficult to make, expensive to use.

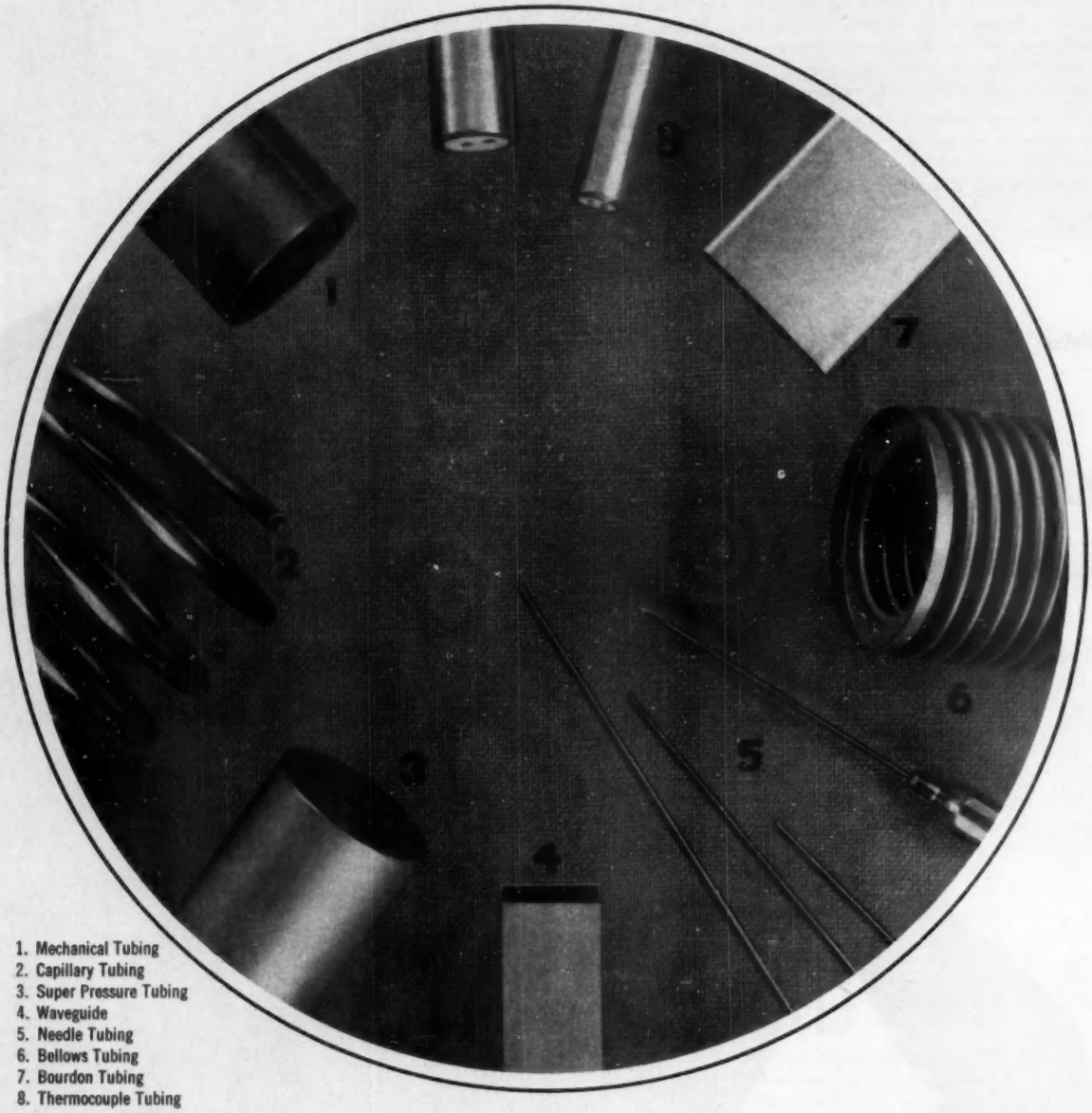
Clearly, then, what's needed is an entirely new and creative approach to switching. An imaginative concept of a static control device which would be inherently capable of handling large ac loads—continuously and endlessly—without wear, deterioration or loss of efficiency regardless of environment. Such a device is described below.

static switch for AC applications

ionic controls

NERVE CELL ANALOGY:
Controlling a large energy potential by small stimulus means through electro-ionic surface impedance changes.

Tubexperience paces



1. Mechanical Tubing
2. Capillary Tubing
3. Super Pressure Tubing
4. Waveguide
5. Needle Tubing
6. Bellows Tubing
7. Bourdon Tubing
8. Thermocouple Tubing

In the design and development of indicating, recording and controlling instruments, more than in any other line of precision products, fine small-diameter tubing is an important component. For instrument designers can readily adapt it to three major application categories: (1) as a conveyor for the fluids (liquid or gas) which operate the fluid-filled systems; (2) as strong, light structural and mechanical elements in linkages, pointers, pen tips and other parts; (3) as special-purpose elements such as torque tubes, manometer tubes, and thermocouple sheathing.

To satisfy the instrument designers' requirements for small-diameter tubing, Superior offers more than 120 analyses in a wide range of sizes, shapes, wall thicknesses and tempers—all to precise tolerances. Bulletin 41 lists materials available, characteristics, production sizes and recommended applications. Write for a free copy today. Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.

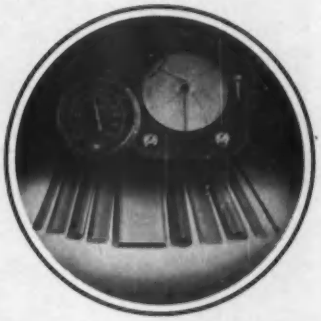
design advances!

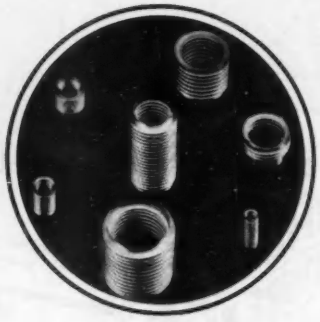
CAPILLARY TUBING

Superior has devoted years to the development of manufacturing processes and quality control procedures for the production of close tolerance capillary tubing. ODs range up to 3/16 in., IDs from .004 through .040 in., lengths up to 3000 ft. Analyses include Types 304, 316, 321, 347 and 446 stainless; also Monel, Inconel,[3] nickel and carbon steel alloys. Data Memorandum No. 11 gives complete details.

BOURDON TUBING

A wide range of analyses, including strain-hardened materials and material which may either be further tempered or precipitation hardened. All are free of inclusions and seams, carburization and decarburization, rough or corroded surfaces, and variations in wall thickness. All offer good creep resistance, low hysteresis, nonrelaxation and excellent fatigue life. Produced in any shape required.





BELLOWS TUBING

Highly uniform in physical and mechanical properties with smooth surfaces that contribute so much to good fatigue life. Extremely ductile with excellent temperature and corrosion resistant characteristics. Free of carburization, dents and pickups. Produced in a wide range of analyses, in both Seamless and WELDRAWN® types, and to specified IDs, ODs and wall thicknesses. Detailed information upon request.

THERMOCOUPLE TUBING

Unusually clean, smooth ID, and produced to very close tolerances. Many analyses including constantan, Chromel P,[1] Alumel,[2] ingot iron, Inconel X,[3] low-carbon nickel, Nichrome V, Monel, and many types of stainless steels. Most materials have high thermal E.M.F. against platinum. Excellent fabrication characteristics. Operating temperatures as high as 2150°F, depending on materials. Sizes through 5/8 in. OD.

Trademarks Reg. U.S. Pat. Off.:
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[2] Hoskins Mfg. Co.
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All analyses .010 in. to 5/8 in. OD—certain analyses in light walls up to 2½ in. OD

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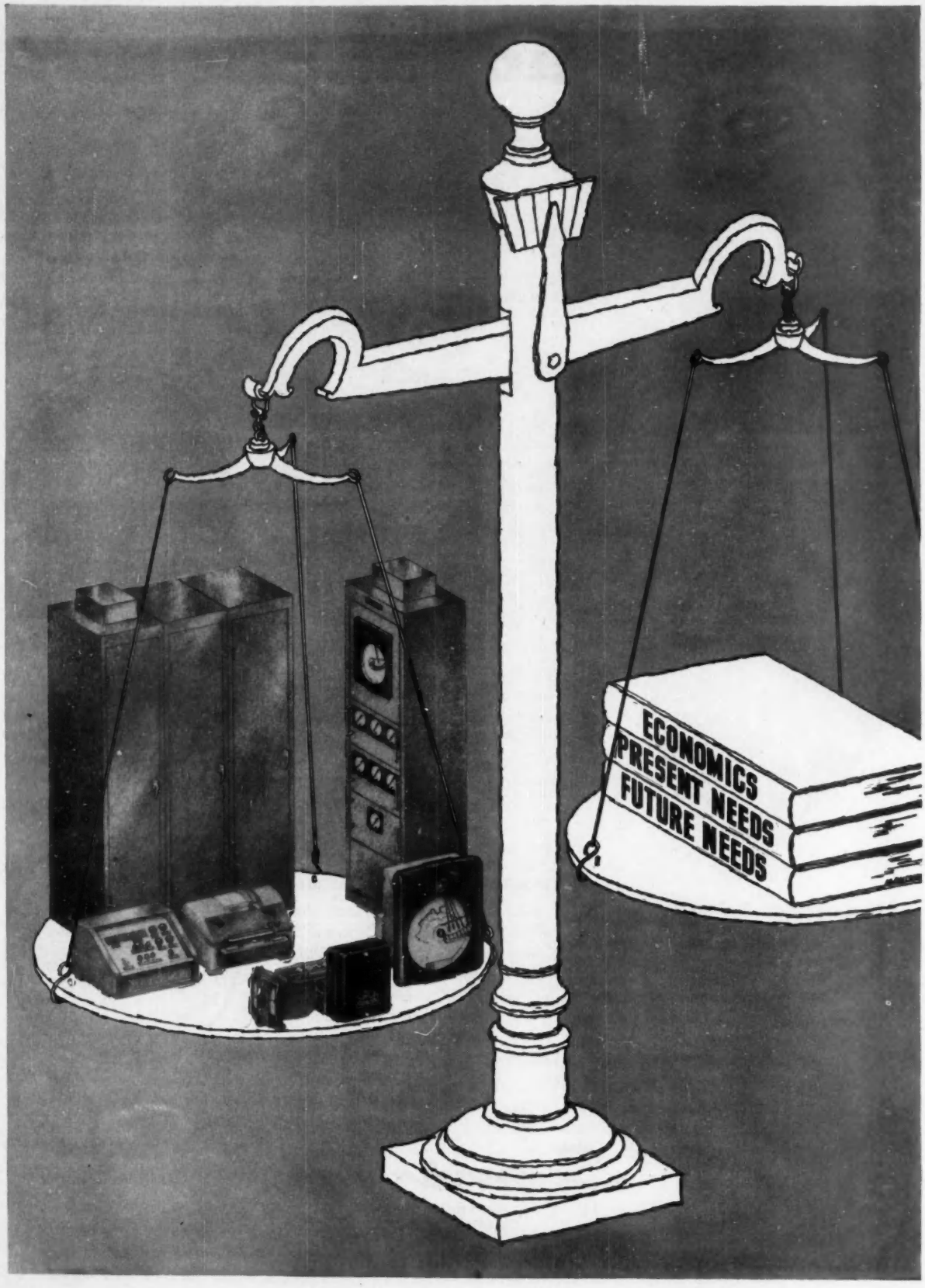
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G150-2

Instruments and controls for power and process

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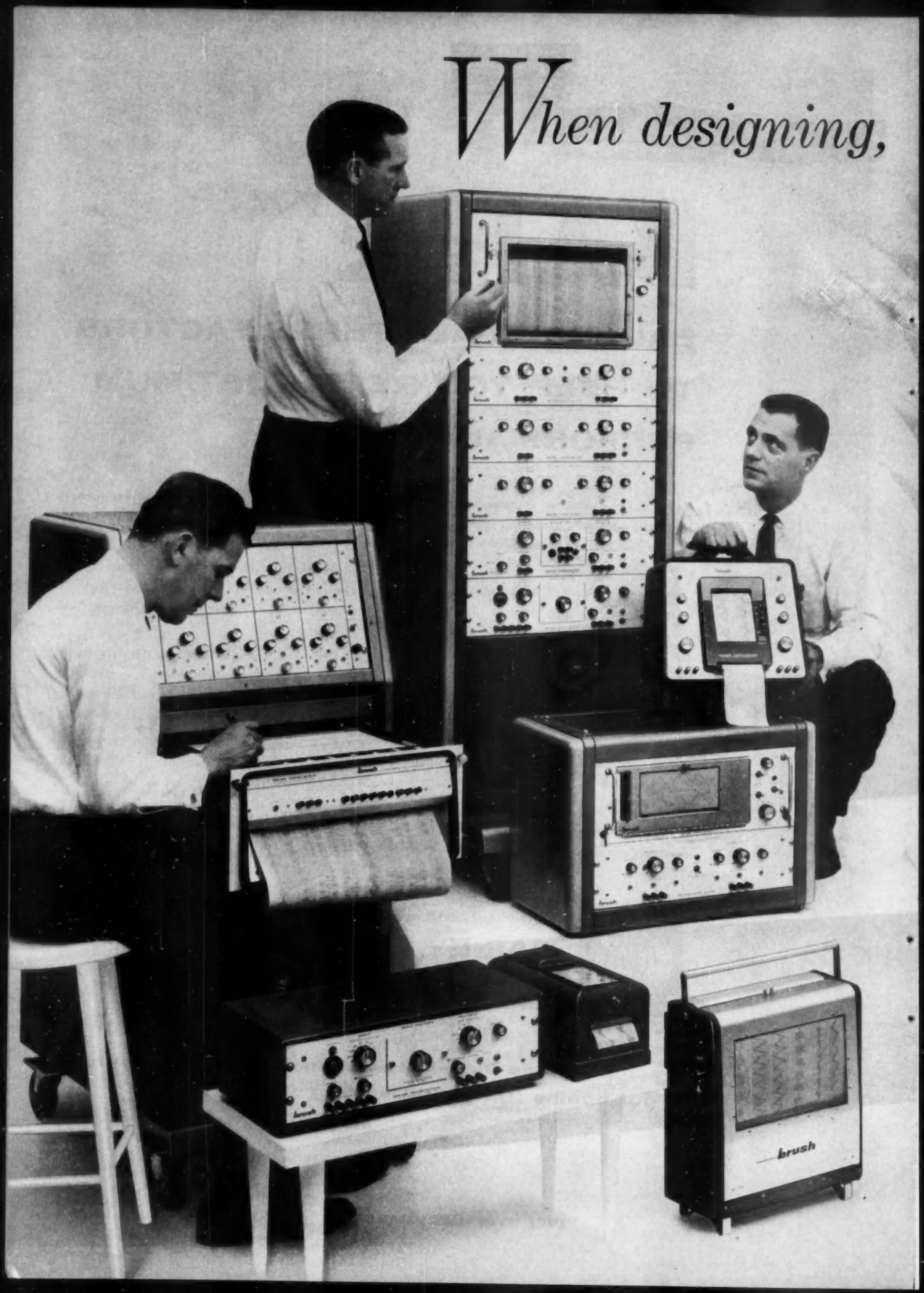
CIRCLE 103 ON READER-SERVICE CARD

CIRCLE 104 ON READER-SERVICE CARD →


When designing,
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testing or monitoring . . .

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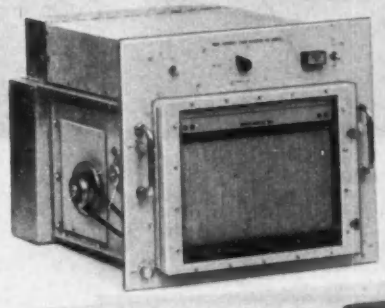

Write for free informative booklet, "New Concepts in Recording." Contains helpful ideas and suggestions.

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THE MARK OF QUALITY

BARBER COLMAN

Wheelco Instruments

Built-in leadership—

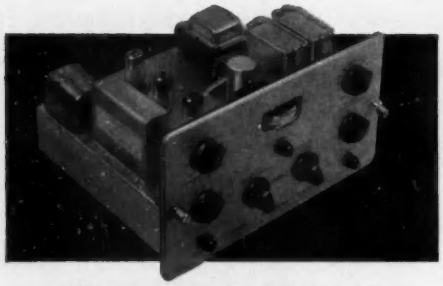
No need to wait . . . get with "field-proved"

There's no need to wait for new designs or hold up a recorder purchase until you're sure that the features you've heard about really work. Wheelco potentiometer recorder controllers — whether circular or strip chart — have the features you want *right now.*

Why settle for less when Wheelco recorder controllers offer you all these as standard — *at no extra cost:*

1. **CONSTANT VOLTAGE SOURCE** — proved in more than three years of field operation and available at no extra cost. Silicon diodes eliminate batteries and standard cells.
2. **QUICK RANGE CHANGE** — no soldering, just loosen 5 screws to replace range change brackets.
3. **PLUG-IN COMPONENTS** — downtime is sharply reduced and repairs can be made without tying up equipment with Wheelco pioneered plug-in components.
4. **ACCESSIBILITY** — inspection, adjustment and cleaning of complete instruments are simplified. Swing-out design

MM SERIES CONTROLLERS FOR PROPORTIONAL RESET AND RATE ACTION

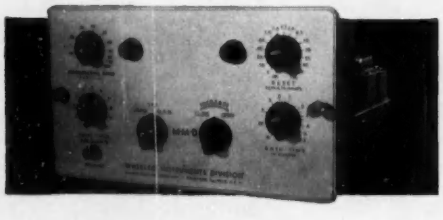


MMC CURRENT OUTPUT TYPE

Flexible in adaptation to final control elements including saturable reactors, electropneumatic transducers, electrohydraulic transducers; as well as other compatible electric systems.

MMP POSITION TYPE

Can operate a valve, valve positioner or other positioning device. Reset action is adjustable from 0.6 to 100 repeats per minute, rate action from 0 to 5.5 minutes.



MMD DURATION TYPE

Regulates input by adjusting on-time of a contactor on either electrical or fuel-fired installations. Ideal when upsets are fast and recovery slow or when large and frequent.

MP PROPORTIONAL POSITIONER

Mounts in the instrument, provides proportional control by modulating the position of final control element as a linear function of the value of the measured variable.

the recorders advanced design

See them in Booth 718 at the ISA Show

of principal elements on all Wheelco recorders permits fast adjustment, chart change, etc.

5. SIMPLE CHANGE OF BALANCING SPEEDS — changing a 15-second recorder to a 2-second recorder requires removing 3 steps of gearing. The two-phase balancing motor remains the same for all speeds.

ALSO FIELD-PROVED CONTROL FORMS WITH EXCLUSIVE MAGNETIC MODULATORS — Proportional rate and reset action on round and strip chart instruments offered by MM series controllers of the current output, position, or duration type.

SERIES 2000 ROUND CHART RECORDERS AND RECORDER CONTROLLERS

are also self-contained, null-balancing potentiometer instruments, the newest in the Wheelco line. Pen speeds are 1, 4, or 20 seconds at 60 cycles a-c. The 12-in. diameter chart has a calibrated width of 4⅝ in. Instrument accuracy is ± ¼ of 1% for all scale spans of pyrometric range. External control point setters are optional. All standard chart speeds are available; also a complete range of control forms including three-function type.

SERIES 8000 RECORDERS AND RECORDER CONTROLLERS

Self-contained, null-balancing electronic instruments designed for long life and trouble-free service. Wide range of models provides for measurement, indication, control, and permanent recording of temperatures and (with transducers) other variables such as speed, strain, ph, and any other quantities that can be resolved into electrical signals. Multipoint recorders handle up to 24 points at speeds from 3 to 24 inches per hour. Multibank (scanner) setups permit recording 144 or more points. Shown at left is recorder controller with automatic reset in tamperproof cover.

Rounding out the Wheelco line

Wheelco 9000 Series multiswitch indicators enable rapid checking of temperatures at as many as 108 stations. More stations require only an additional switch housing cabinet.

Circular scale 3000 Series indicators and Indicating Controllers have large, bold, distant-reading scales and generally parallel construction of 2000 Series recorders described above.

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Planning Efficient Tests

Testing yields information; this information may be vital in the study of instrumentation and control systems, in determining control characteristics of processes and equipment, or in evaluating physical and performance characteristics unrelated to control. Even though the end use of the test information varies, the common denominators of measurement, data transmission, and data recording and processing bring testing within the franchise of the control engineer.

HARRY R. KARP
Control Engineering

Valid information is essential to research and design of new processes and control systems and the improvement of existing ones. Such information is obtained by interpreting data, and data are the results of actual tests of real or simulated systems. Data can also be obtained by analysis of fundamental physical and chemical relationships, but it does not follow that analysis and test are mutually exclusive. In fact, just the opposite is the case. On one hand, it is not realistic or practical to carry out a test program unless some reasonable idea exists—from analysis or simply from observation—about the characteristics of the system under consideration. On the other hand, an analysis may establish the system's character, but testing will still be needed to determine actual values to be used in conjunction with the analytical information.

Testing falls directly into the control engineer's province. In carrying out a test program, the control engineer is faced with three problems:

- organizing efficient tests
- determining what physical unit to test
- adapting to the specific test project the functions common to all tests, those of measuring test variables and transmitting, recording, and processing the test data.

Organizing efficient tests

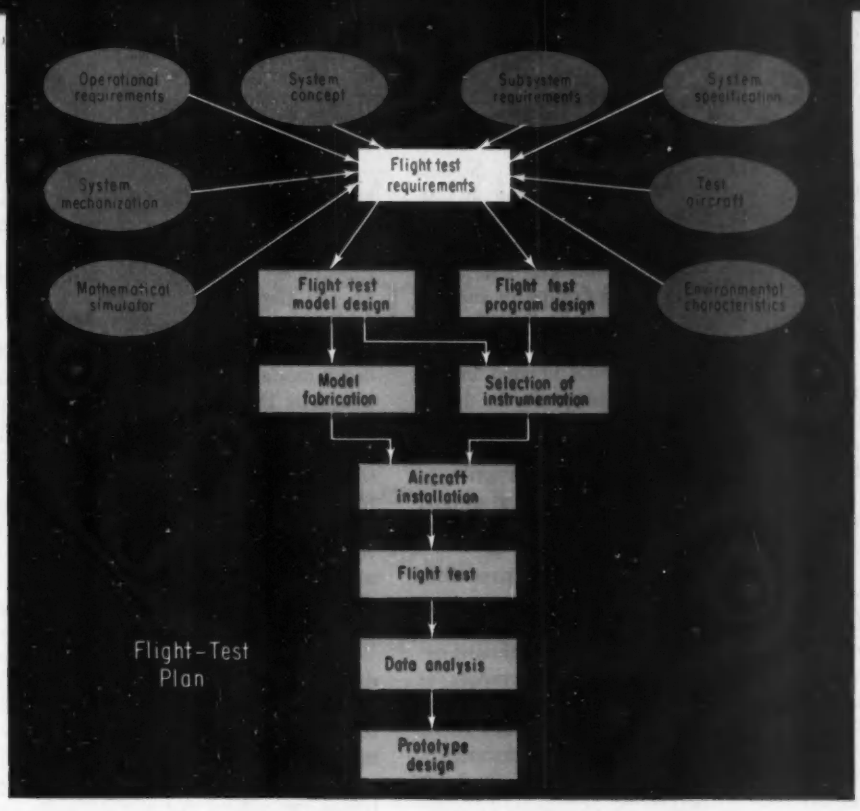
Planning involves such considerations as determining what information is desired, what variables to test, how to manipulate the variables, what instruments to use, what measurement precision is needed, how to coordinate the tests, how much the tests will cost, and how to modify the test program as partial information is gleaned from the initial test runs.

All test programs do not raise such formidable problems. Sometimes the information sought is easily detectable, accuracy of measurement may not be too important, and the interpretation of results may require only plotting the data on graph paper. Such may be the case if it is desired to find the effect of the presence or absence of a qualitative variable, for example the effect of vibration on instrument accuracy. When several variables act simultaneously it may be difficult to screen out the important ones. Then it becomes necessary to use statistical methods both to plan an efficient set of tests and to detect—possibly in the presence of noise—those variables which do affect operation.

Many test programs require a considerable amount of technical competence, not only in instrumentation and control, but also in such other technical fields as aeronautical and missile engineering, statistics and mathematics, and digital computer programming for data analysis. Furthermore, large test programs call for good administrative organization because of the many specialized groups working together on the program. V. G. Fauque of Westinghouse/Air Arm elaborates on many phases of technical and administrative testing organization in an excellent AIEE paper, "System Considerations in Flight Test Planning", June 1959. The figure is taken from this paper.

Determining what physical unit to test

Depending on the test purpose, it may be feasible to interrogate an operating or full-scale plant. Probably the most valid data are obtained here. However, practical considerations like lost commercial value,



extraneous disturbances, and psychological opposition from operating personnel—or the fact that the full-scale plant does not exist—may require that tests be performed on such other physical units as reduced-scale models of equipment, pilot-plants, computer-simulated systems, and breadboard mock-ups closely paralleling actual control systems.

Often, these simulating devices exist for reasons other than determining control characteristics. Pilot-plants, for instance, are used by chemists and chemical engineers primarily to try out new processes, catalysts, and raw materials. However, to some extent the pilot-plant also generates information useful for deducing operation and control of its full-scale counterpart. Considerable emphasis is now being placed on gathering data on pilot-plants for determining control characteristics of full-scale processes via automatic data loggers and digital computer data analysis.

At the other extreme are these scale models—like wind tunnels and scaled-down versions of aircraft and missiles—whose virtual reason for existence is to facilitate tests. They are, in fact, information factories. Much of scale-model test work is related to control, but even where test data do not end up in the design of control systems, the vast amount of instrumentation, recording, and data-processing equipment requires the attention of hundreds of instrument and test engineers.

Models simulated on computers, particularly electronic analog computers, offer many benefits in carrying out a test program. An important gain is that tests which would be considered outrageous in the field, but which are nevertheless important for control system design, can be carried out in complete freedom on the simulator. An example would be to find out what would happen if the electric utility service for a manufacturing or processing operation experienced a 50-percent drop in voltage for 20 seconds. Information about the effect of such a disturbance is essential in developing adequate safety controls, but it is doubtful if anyone would deliberately introduce the power outage and jeopardize plant operation.

For scale or simulated models to yield useful data, they must represent with some faithfulness their full-scale counterparts. More likely than not, an exact simulation will be difficult. When the system which is to be simulated already exists, it may be possible to improve the simulation by running some preliminary tests on the system and then running the planned test program on the simulator. The design changes or improvements deduced from the simulator tests are introduced into the full-scale plant or control system, and then the plant or control system is again tested to see whether the changes were as beneficial as indicated from the simulation tests. Thus, tests are used at several stages of design and improvement. Test information is traded back and forth between scale or simulated models and their full-scale prototypes.

A technique gaining some favor, particularly in the aircraft industry, is that of combined analog-digital simulation. It can be used to great advan-

tage in carrying out certain test programs. Signals for navigating, operating, and controlling an aircraft often occur in discontinuous form and therefore are compatible with digital control computers. The aircraft itself can be simulated best on a general-purpose electronic analog computer and the control system on a general-purpose digital computer. Then the combined simulation can be tested to determine improvements needed in the aircraft and the corresponding changes in the digital controller. Similarly, some aspects of the control computer—like sampling rate—can be tested to see what effects they have on aircraft operation. In short, the design of the process or plant prototype and its digital control system can be carried out simultaneously.

Not to be overlooked is the fact that many control systems must be created and made operative with minimum elapsed time. Design of such control systems can be facilitated by breadboarding. Under these circumstances such requirements as weight, size, and even low cost ordinarily set down for control systems may be waived, but not those requirements related to function and performance. To prove the controller's suitability for in-plant use may call for tests to determine accuracy, dynamic response, and operation under severe environmental conditions. When, as a result of tests, an offending component or subsystem is detected, it must be capable of being removed and replaced by a suitable unit without difficulty or system redesign. Breadboarding offers the important advantage of permitting easy modifications following testing.

Common testing functions

Common to all testing projects are the three stages of measuring test variables, transmitting the test information, and recording and processing the test data. The emphasis placed on these aspects of testing will vary, depending on what type of physical unit is being tested, the nature of the desired information, the location of the tested unit, and the amount of backup talent and facilities (computers, statisticians, operating personnel, and technicians) available to carry out the test and process the data.

All good practices associated with selecting and installing transducers and sensing elements for normal plant operation apply as well to selecting transducers for measuring test variables. These practices include attention to accuracy, resolution, speed of response, drift, and subsequent signal conditioning and transmission. However, the measurement of test variables may impose some additional and peculiar conditions on the transducers. Among these are small size (for use in testing scale models), portability (for use with portable test gear shipped from location to location), temporary attachment (such as strain gages), and one-shot use (in missile testing).

Often measurements of a certain effect or variable are made during tests but no similar test is made during normal operation. Because of the few-times basis of such measurements, the necessary transducer may not be commercially available. Special transducers will have to be developed to meet testing requirements. This is certainly the case in testing aircraft and missiles and their scaled-down models, as witnessed by the numerous reports issued by the National Aeronautics and Space Administration dealing with the design of special measuring elements. To some extent, a similar situation exists in making tests in the raw materials processing industries. Here, users wanting to measure stream composition were forced to develop such stream analyzers as chromatographs, moisture analyzers, and photometric analyzers. Originally for limited testing, these transducers are now used for continuous in-plant measurements.

Once the test transducers have been selected or developed, the next consideration is how the test data will be transmitted from the test site to the recording site. For many tests, this will not be much of a problem since all that will be required is to run a few pairs of wires (or perhaps pneumatic tubes) some short distance between the transducers and recorders. However, the testing of distant, far-flung, or inaccessible systems does raise some interesting data transmission considerations. Among these are the matching of the transducer to the transmission link and then matching the transmission link to the recording and data processing equipment. Overall, a comparison of radio, wire, and pneumatic methods of data transmission should be made on the basis of fidelity, noise and noise levels, reliability, economics, and flexibility.

Once the test data have been transmitted back to a central collection station, the remaining problems are to record the data and to get them into useful form as quickly and economically as possible. This requires a study of data-recording, data-processing, and computing techniques and equipment.

The recording media must be consistent with the static and dynamic characteristics of the test data. Considerations include recorder accuracy, whether the data will be recorded in analog or digital form, whether automatic or manual logging will be employed, and whether the dynamic response of the recording means is fast enough to faithfully record the dynamics of the test data.

The foregoing discussion presents an overall look at testing for design and improvement of control systems and controlled equipment and processes. The succeeding articles in this theme issue on testing expand on many salient points in the three main phases of testing: planning; interrogating full-scale, reduced-scale, and simulated systems; and measuring, transmitting, and recording test data. The issue concludes with 12 industrial and military applications of testing.

Designing and Interpreting Tests

STATISTICAL METHODS REVEAL HOW TO
Get maximum information with minimum testing
Design small experiments which can still yield important data
Improve precision with repeated tests
Detect important variables
WHEN TESTING TO DETERMINE
Which variables must be controlled
How instrument errors affect process outputs
How environmental changes affect control accuracy

J. S. HUNTER
Statistical Techniques Research Group
Princeton University

In running efficient tests, statistical techniques help at two intermediate stages: in the design of the experimental program and in the analysis of data. Data analysis provides plausible explanations of experiments, in turn, performs an important tester's ability to generate new ideas. The design of experiments, in turn, performs an important function in a test program since the ability to provide meaningful analysis of experimental data rests in large part on the nature of the data themselves.

The 2^2 factorial design

Suppose the steady-state effect of two variables, temperature and pH, on some response y (yield) of a chemical reaction is to be investigated. Let two levels of temperature, 35 and 40 deg C, and two levels of pH, 4.0 and 4.3, be simultaneously studied. If the high and low levels are represented by +1 and −1 of the experimental design variables x_1 (temperature) and x_2 (pH), the resulting experimental design can be tabulated—and illustrated geometrically—by four points which form the vertices of a square in the coordinate system x_1 and x_2. Figure 1 shows the single observation recorded at each experimental point in tabular and geometric form. (The experiments should be run in random order. The y subscripts are not necessarily the order of the experimental runs.)

Considerable information can be obtained, even

Temperature	pH	Response	Design levels x_1	Design levels x_2
35	4.0	$y_1 = 4$	−1	−1
40	4.0	$y_2 = 6$	1	−1
35	4.3	$y_3 = 7$	−1	1
40	4.3	$y_4 = 10$	1	1

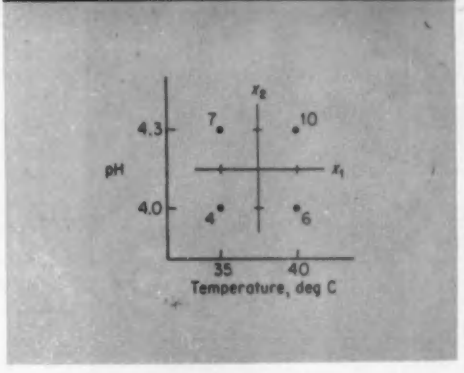


FIG. 1. Tabular and graphical representation of a two-variable two-level test.

from such a simple experimental program, about the effect on the response of changing temperature alone, pH alone, and temperature and pH combined. For either setting of pH effect on the response of changing temperature from 35 to 40 deg C is quickly estimated by calculating:

$$y_H - y_L \quad (1)$$

where y_H is the response at high temperature and y_L at low temperature. Figure 1 shows that two temperature effects, one at the high level of pH (10-7) and the other at low pH (6-5). The average of these two temperature effects, called the temperature main effect, can be simply calculated.

Estimated main effect of temperature

$$= y_{H\,avg} - y_{L\,avg} \quad (2)$$
$$= \tfrac{1}{2}(y_2 + y_4) - \tfrac{1}{2}(y_1 + y_3)$$
$$= \tfrac{1}{2}(10 + 6) - \tfrac{1}{2}(7 + 4) = 2.5$$

Similarly, the estimated main effect of pH which results from changing pH from 4.0 to 4.3 is also found by calculating $y_{H\,avg} - y_{L\,avg}$, where now the subscripts H and L refer to average responses at high and low levels of pH.

Estimated main effect of pH

$$= \tfrac{1}{2}(10 + 7) - \tfrac{1}{2}(6 + 4) = 3.5$$

The estimate of the main effect of pH is independent of the temperature main effect, and vice versa; that is, the magnitude and sign of either does not affect the other. This independence of estimated main effects is one important characteristic of the two-level factorial design. Another is the ability to estimate the interaction effect between the two variables of interest.

Interaction effect

An interaction between two variables implies either a synergistic effect (total effect is greater than the sum of two effects taken independently) or antagonistic effect on the response when variables act together. For example, if increasing temperature alone increases the response by two units and increasing pH alone increases the response by three units, but increasing temperature and pH simultaneously increases the response by only one unit, then temperature and pH are said to interact. The 2^2 factorial design provides independent estimates of the main effects and interaction effect. In the notation of experimental design variables x_1 and x_2, the interaction effect is sometimes indicated by x_1x_2.

To measure the interaction effect, the main effect of x_1 is calculated at high x_2 and again at low x_2. The average difference in these two estimates of the x_1 main effect is the interaction effect. Thus, returning to the data given in Figure 1:

Estimated interaction effect

$$= \tfrac{1}{2}(10 - 7) - (6 - 4) = 0.5$$

Interval estimates for true effects

The calculated main effects and interactions given above are statistics. These statistics estimate parameters, the true values of the main effects and interactions. These statistics can not equal the parameter values since the observations from which the statistics are derived are subject to error. However, it is possible to provide an interval estimate for a parameter. The construction of an interval estimate for a parameter is of great practical importance. For example, the interval states: 1) that all values suggested for the parameter lying outside the interval are contradicted by the data—if any one of these values for the parameter are true, then the observed data can only be viewed as a rare event, and 2) that all values suggested for the parameter that fall within the interval are *not* contradicted by the data—the data cannot be considered unusual for any of these parameter values.

Using the data given in Figure 1, no interval can be made for any of the parameters (the main and interaction effects of pH and temperature) since no estimate of error variability is provided by the data. A valid estimate of the error variation is provided only when an experiment is repeated. Suppose now that instead of the original test program of four runs, the entire experimental design had been replicated (repeated). The results of the first and second test programs are shown in Figure 2. The estimated main effects are once again obtained by calculating $y_{H\,avg} - y_{L\,avg}$ for each variable. Thus:

Estimated main effect of temperature

$$= \tfrac{1}{4}(y_2 + y_4 + y_6 + y_8) - \tfrac{1}{4}(y_1 + y_3 + y_5 + y_7) = 2.5$$

Similarly:

Estimated main effect of pH = 1.5
Estimated interaction effect = 0.5

Provided the errors made in recording observations are independent of one another, the variance V of the estimated effect is:

$$V(y_{H\,avg} - y_{L\,avg}) = (2s^2/n) \quad (3)$$

Control variables		Design variables		Response
Temperature	pH	x_1	x_2	y_i
35	4.0	-1	-1	$y_1 = 4$
40	4.0	1	-1	$y_2 = 6$
35	4.3	-1	1	$y_3 = 7$
40	4.3	1	1	$y_4 = 10$
35	4.0	-1	-1	$y_5 = 6$
40	4.0	1	-1	$y_6 = 10$
35	4.3	-1	1	$y_7 = 7$
40	4.3	1	1	$y_8 = 8$

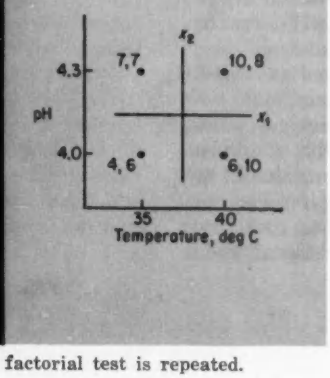


FIG. 2. To improve precision, the 2^2 factorial test is repeated.

where s^2 is the estimated error variance of single observations and n is the number of observations (in this case, four) used to find each average.

The error limits for the estimated effects are then found from:

$$(y_{H\ avg} - y_{L\ avg}) \pm t_\alpha(2s^2/n)^{1/2} \qquad (4)$$

where t_α is "Student's t-statistic" and $1 - \alpha$ is a probability level chosen by the experimenter. Tables of the t-statistic were developed (1908) by W. S. Gossett; the tables are entered with α and with ν, the number of degrees of freedom involved in the estimate of variance.

Thus the interval estimate for any of the true effects estimated from the 2^2 factorial design is given by

$$\text{Probability} \left\{ (\text{estimated effect}) - t_\alpha(2s^2/n)^{1/2} \leq \delta \leq (\text{estimated effect}) + t_\alpha(2s^2/n)^{1/2} \right\} = 1 - \alpha$$

where δ is the true effect. Here, s^2, a pooled estimate of the experimental error variance, is calculated from:

$$\frac{\nu_1 s_1^2 + \nu_2 s_2^2 + \cdots \nu_k s_k^2}{\nu_1 + \nu_2 + \cdots \nu_k} = s^2$$

because tests have been repeated at more than one experimental point. Independent estimates of the variance are made at each set of repeated runs by calculating $s^2 = \Sigma\ (y - y_{avg})^2/(N - 1)$ at each point and these estimates are pooled according to the preceding equation. Each of the estimates has $\nu = N - 1$ degrees of freedom and hence the pooled estimate has $(\nu_1 + \nu_2 + \ldots \nu_k)$ degrees of freedom. (In this example, four.)

For the replicated test, Figure 2, $t_\alpha\ (2s^2/n)^{1/2} \cong 3$ at a probability level $1 - \alpha = 95$ percent, giving the intervals:

$$\text{Prob} \left\{ -0.5 \leq \text{true main effect of temp} \leq 5.5 \right\} = 0.95$$
$$\text{Prob} \left\{ -1.5 \leq \text{true main effect of pH} \leq 4.5 \right\} = 0.95$$
$$\text{Prob} \left\{ -3.5 \leq \text{true interaction effect} \leq 2.5 \right\} = 0.95$$

The practical interpretation of the interval estimate is that all postulated values for the true effects that lie within the interval cannot be refuted by the experimental evidence, while all postulated values lying outside the interval are rejected at the indicated level of probability. These intervals are sometimes called confidence intervals. It is clear from Equation 4 that as the number of observations, n, increases the interval estimate decreases; as a consequence, the true effect can be estimated with more and more precision. Said another way, the knowledge of the true effect increases as n increases. In this example, n was increased simply by repeating the test program.

The 2^3 factorial design

A 2^3 factorial design test program contains eight separate experiments and consists of all possible combinations of three variables each held at two levels. The coordinates of the eight points shown in Figure 3 are of the form $(\pm 1, \pm 1, \pm 1)$ and they define the vertices of a cube in the space of x's. The observations noted at each experimental point (for temperature, pH, and concentration) are listed in the associated table.

The main effect of each variable is now quickly determined by calculating $y_{H\ avg} - y_{L\ avg}$ where, as before, the subscripts stand for the average response at the high and low levels of each variable. For the data given in Figure 3, the estimated main and two-factor interaction effects are

Main effects:

- temperature $(x_1) = 1.0$
- pH $(x_2) = 1.0$
- concentration $(x_3) = 0$

Two-factor interactions:

- temperature by pH $(x_1x_2) = -2.0$
- temperature by concentration $(x_1x_3) = -1.0$
- pH by concentration $(x_2x_3) = 1.0$

Design coordinates			Response
x_1	x_2	x_3	y
−1	−1	−1	1
1	1	−1	3
1	−1	1	3
−1	1	1	5
1	1	1	4
1	−1	−1	6
−1	1	−1	4
−1	−1	1	2

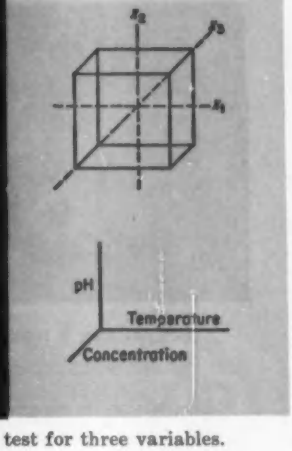


FIG. 3. Design of a factorial test for three variables.

As in the case of the 2^2 factorial design, all estimates are independent of one another.

The variance of these estimates can be found from Equation 3, where n, the number of observations entering each average, is again equal to 4. The variance is identical to that obtained from the replicated 2^2 factorial design. Thus, the precision of estimates is the same whether using a replicated 2^2 or a single 2^3 factorial design. However, the 2^3 design provides independent estimates of *three* main effects as well as the *three* two-factor interactions, whereas the 2^2 factorial only permits the independent estimation of two main effects

and a single interaction between two variables.

Fractional factorial designs

Test programs consisting of all possible combinations of two levels of k variables give rise to the 2^k factorial design. As k increases, the number of test points rapidly becomes large and the size of the experimental program becomes quite cumbersome. Fortunately, small fractions of the 2^k factorial designs permit estimation of main effects of k variables and, with larger fractions, the two-factor interactions as well.

The simplest fractional design is the one-half replicate of the 2^3 factorial, sometimes denoted as 2^{3-1} factorial designs. The two one-half replicates are shown in Figure 4, one by the set of four black dots and the other by white dots. Either one-half replicate permits independent estimates of all three main effects.

However, one consequence of using either 2^{3-1} design alone is that independent estimation of main effects *and* interaction effects is no longer possible. In fact, an x_ix_j interaction term, if it exists, will bias the x_k main-effect estimate. Thus, if one of these fractional factorial designs is used, it is necessary to assume that the two-factor interactions are zero or negligible compared to the main effects. If both half-replicates are run in sequence (equivalent to a 2^3 design), the resulting data will provide independent estimates of the main effects *and* the three two-factor interactions. As k becomes larger, suitable fractional designs—such as 2^{k-2} (1/4-replicate), 2^{k-3} (1/8-replicate), and 2^{k-4} (1/16-replicate)—can be designed.

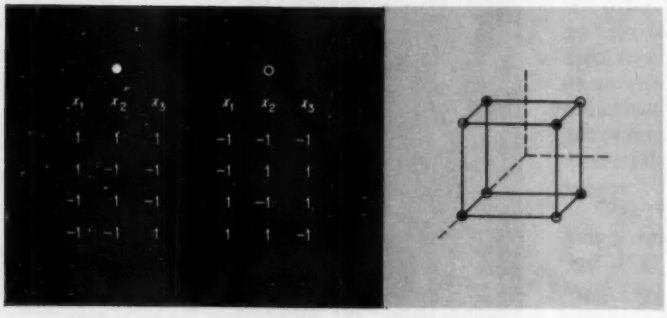


FIG. 4. Two ½ replicates for a three-variable experiment.

Sequential use of fractional factorials

As noted above, one consequence of using fractional factorial designs is that, depending on the design, main effects may become confounded with interaction effects, and interaction effects confounded with one another. Two estimates are said to be confounded when the calculations for both estimates require the observations to be used in an identical manner, that is, the $y_{H\,avg} - y_{L\,avg}$ for the two effects ends up using the same pair of averages. However, this difficulty is less severe than it at first appears.

In the beginning of a program to screen for the important effects among k variables—where k is large—a highly fractionated design can be used initially. On analysis of the results of this first experimental program a second can be designed to obtain further information on those suggestions provided by the first program, while simultaneously breaking up only those confounded effects that look to be most important. Thus, the overall experimental program can grow gradually in size, composed of small blocks of runs each comprising some particular fractional factorial and in the aggregate providing a factorial or fractional factorial design specifically tailored to the signals obtained.

The sequential use of fractional factorial designs permits the experimenter to frequently review the data, pursue those signals which appear most important, and if needed, to change his mind about the variables to be studied, the ranges over which they are to be varied, and their metrics as the experimental program proceeds. Clearly, a final overall design containing N experiments resulting from such a sequential program will rarely be the same as a program of N experiments that might have been planned from the beginning. The sequential program helps guarantee that experimental time and energy is spent where it will do the most good.

Yates Algorithm

For tests involving a few variables, the estimation of effects is relatively simple. For instance, in the example of the 2^3 factorial design the list of the main and two-factor interaction effects shows that temperature-by-pH interaction gave the largest effect, minus 2 units, while other effects were only 1 or 0 units. These values were estimated by calculations of the form: $y_{H\,avg} - y_{L\,avg}$. However, several shortcuts have been proposed for large k; the best is the Yates Algorithm (Ref. 1 and 2).

The Yates Algorithm is demonstrated, Figure 5, on the 2^3 factorial design, involving temperature, pH, and concentration, used previously with responses as shown in Figure 3. The left column (of Figure 5) contains shorthand notation for specifying which variables are at their high levels and which are at low levels. In this column, writing x_1, for instance, is the same as writing $+1, -1, -1$, while x_1x_2 means $+1, +1, -1$. Thus, only variables at high levels are written in the left column. Note that Figure 5 contains two equal sets of rows.

Once the variables combinations and their re-

Treatment	Response	1	2	3	Effects
(1)	1	7	14	28	3.5 (avg)
x_1	6	7	14	4	1 (T)
x_2	4	5	4	4	1 (pH)
$x_1 x_2$	3	9	0	-8	-2 (T × pH)
x_3	2	5	0	0	0 (C)
$x_1 x_3$	3	-1	4	-4	-1 (T × C)
$x_2 x_3$	5	1	-6	4	1 (pH × C)
$x_1 x_2 x_3$	4	-1	-2	4	1 (T × pH × C)

FIG. 5. Calculating main and interaction effects of a 2^3 factorial design using the Yates Algorithm.

sponses are set up in this standard order the Yates method proceeds in this manner:

1. Add responses in the first and second rows and insert the total in row 1, column 1. Add the next pair and set total in row 2, column 1. Add pairs until the top half of column 1 is filled.
2. Next, subtract response in row 1 from response in row 2; insert difference in row 5, column 1. Continue with succeeding pairs until bottom half of row 1 is complete.
3. Continue steps 1 and 2, using column 1 to form column 2.
4. Continue steps 1 and 2, using column 2 to form column 3.
5. Continue in this manner until the number of columns equals k, the number of test variables.
6. Divide each value in the final column by 2^{k-1} or $2^{3-1} = 4$ in this case; except the first row, the total response (28) is divided by 2^k or 8 to yield average response. The effects obtained in this manner are the same as those determined by the $y_{H\,avg} - y_{L\,avg}$ method.

The responses in this test were from a single observation for each test. If n observations are made for each point, then the total is entered in the response column, the procedure carried out to the kth column, and the values in column k divided by $2^{k-1}n$, except row 1 which is divided by $2^k n$. Using n observations per test point permits an independent estimate of the error variance and permits the construction of interval estimates.

Qualitative variables

The preceding discussion of the two-level factorial design assumes the k variables are quantitative. The procedure is equally valid in studying the effect of the presence or absence of qualitative variables, such as the effect of the presence or absence of vibration on instruments as caused by a pump running. In these circumstances it is usual to let −1 represent absence and +1 presence of the qualitative variable. The calculation and interpretation for the effect of qualitative variables follows identically that described above for quantitative variables of interest.

Estimating response surfaces

If a steady-state response y is related to some variable x it is frequently illustrated empirically by a straight line, or by some simple curve. Similarly, if a response y is related to more than a single variable the response can be illustrated geometrically by a plane surface or a curved surface in two dimensions, and by multi-dimensional analogs of these surfaces for more than two variables. When the response function can be represented adequately by a planar surface, the two-level fractional factorial designs provide all the information necessary for the actual mapping of the response over the region of interest.

Of course, the combined effects of changes in several variables $x_1, x_2, \ldots x_k$ upon a response y may not always be so simply expressed. For example, the interaction effect is a signal of the non-additivity or non-planarity of a response function, and simple curvature of a response over the range of study is another. Fortunately, experimental designs exist, constructed in part from the two-level factorial designs, which permit the estimation of these more complex response functions. For example, in the case of two variables x_1 and x_2 the four additional points (1.41, 0), (−1.41, 0), (0, 1.41), and (0, −1.41) would be added to the two-level factorial design given in Figure 1 to give the vertices of an octagon. This experimental design, which may be constructed sequentially starting with the 2^2 factorial, permits the estimation of a curved response function (surface) over the experimental region. For further details of this useful statistical methodology, see References 3 and 4.

REFERENCES

1. *THE DESIGN AND ANALYSIS OF FACTORIAL EXPERIMENTS*, F. Yates, Imperial Bureau of Soil Sciences, 1937.
2. *EXPERIMENTAL DESIGNS*, W. G. Cochran and G. M. Cox, John Wiley & Sons, Inc., 1957.
3. *THE EXPLORATION AND EXPLOITATION OF RESPONSE SURFACES*, G. E. P. Box, "Biometrics", Vol. IV, 1954.
4. *EXPERIMENTAL DESIGNS IN INDUSTRY*, V. Chew, editor, John Wiley & Sons, Inc., 1958.

Practices and Problems of Interrogating an Operating Process

THE GIST: Here, the distillation column is singled out to convey the realistic situation of testing continuously operating processes. Test purposes, test procedures, and data analysis methods are covered, keeping in mind the primary consideration that such processes must operate—even while being tested—to make a profit. To the fluid process control engineer, the problem is how to carry out tests when confronted with the requirement that testing must interfere as little as possible with production. The practical advice given here will apply as well to interrogating other systems for which the need for continuous operation is not so severe. Author Weiss intersperses his discussion with specific descriptions of what Sun Oil Co. is doing to facilitate process testing in the field.

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An operating process in a petroleum refinery is constantly being interrogated, the broad intent of such tests being to maintain or improve the money-making abilities of the operation. The questions put to the process range from an operator's hour-to-hour informal scan of instruments and records to some infrequent but formal test schedule. The amount of work in getting and interpreting answers also has a wide range, from an immediate, almost intuitive, "Everything is OK", to intensive data analysis wringing all possible information from a collection of records.

Test purposes

While the main purpose of testing is to improve process profitability, this economic intent must be narrowed down to subordinate purposes to classify the types of process testing. These classifications, in turn, govern the extent of the tests and the variables to be measured. The major test purposes are to:

- explore actual operating conditions
- explore process limitations
- explore process stability and dynamics

Exploring operating conditions

Testing of actual operating conditions is generally performed under two different circumstances, reflecting two different philosophies of process operation. Either the process is assumed to be static or it is assumed to be changing with time.

The traditional view of a petroleum process is that it operates mostly in the steady state. Then, plant surveys—to measure process efficiency; to justify clean-up, repair, or equipment modification; and to accumulate experience for design of future equipment—can be undertaken when it is believed the plant will be in a stable, undisturbed condition. Perhaps, more realistically, it will be necessary to choose for analysis only the data obtained during that portion of the test period when things actually turned out to be quiet.

These surveys generally require special instruments, frequent analysis of feed and product stream samples, and sufficient manpower (insuring that measurements and grab samples are taken simultaneously) to yield careful overall measurements. Such special effort points out that, while plant instrumentation and stream sampling schedules may be adequate for plant operations, they are inadequate for precise determination of plant performance.

Steady-state surveys are usually made at only a few of many possible operating conditions. One reason for this limitation is the expense of such tests—the cost increasing with the test duration, number of men required, and amount of analysis (of materials, samples, and test results) involved in carrying out the test. For example, a simple survey of a furnace or a light-ends distillation tower costs less than $1,000, while a full survey of a catalytic reformer costs over $3,000. Another reason for limited testing is that the general region of best operation is known beforehand from plant design data and from review of daily records.

A somewhat different exploration of actual operating conditions must be undertaken if it is recognized that the steady state is only an approximation to the actual operating mode of many processes. For example, distillation columns are often subject to so many uncontrollable external disturbances that they are continuously in transition from one condition to another. Typical external disturbances include

changes in feed composition, enthalpy, and cooling-media temperature—plus changes in operating instructions from management. Investigations of such transitory processes require that measuring equipment be suitably responsive to dynamic variations, that each recorded measurement be carefully marked as to time of occurrence, that discontinuously recorded variables be measured frequently enough to define time-varying phenomena, and that the test program be carried out when typical conditions prevail.

Of these requirements, the last one, typical conditions, is the hardest to achieve. Only if measurements are continued for an indefinitely long period does one get any assurance that he has recorded the usual situation, and it is clear that the cost of an indefinitely long experiment is definitely excessive. One must always settle for inadequate data.

To explore operating relationships for process improvement, Sun Oil Co. is installing a control center at its Marcus Hook refinery. The control center will contain an array of commercial and special stream analyzers, strip-chart recorders, and numerous other special instruments for temperatures, pressures, and the like—all operating in parallel with regular plant instruments—to facilitate efficient interrogation of a commercial, 60,000 barrel per day catalytic cracker and associated fractionators. This is a joint investigation by Sun and Genesys looking toward possible eventual control by a computer.

Exploring process limitations

Other tests investigate the character, size, and occurrence of limitations on process operation. Although some limitations may be associated with dynamic operation, it is usual to consider only those thought to be a consequence of static or steady state operation.

While calculations can often predict those operating conditions that will produce such limitations as too much side products or excessive catalyst deterioration, they are often verified by supplemental tests. However, deliberate testing for these limitations is generally confined to pilot-plant or semi-works operation. Process limitations related to efficiency are rarely deliberately explored in a full-scale refinery process. What little is known about operating limitations is extrapolated from pilot-plant work or found out when normal operation accidentally wanders into a limiting region. In this way, the daily operating records may be looked on as a continuous test to explore limitations.

To explore process operations, limitations, and control, Sun has a commercial, 200-bpd distillation column separating normal butane from isobutane, operated by the refinery but available at any time for tests. Its purposes are to improve understanding of distillation operation (flooding conditions, for instance) and control of operating points. It will also serve as a field test medium for trying out such new control concepts and equipment as the Westinghouse OPCON optimizing controller and the Litton-80 digital differential analyzer computer, both for closed loop control. The column is instrumented for test purposes far beyond normal: there are gas chromatographs at the input and both output streams, stream-sample taps and thermocouples at alternate trays, and electronic instrumentation for signals compatible with computers.

Exploring process dynamics

The intelligent design and adjustment of a control system requires a knowledge of process dynamics. No amount of fancy mathematical analysis will compensate for the lack of dynamics information. Furthermore, there is a growing awareness that improved process operation and design will rest in part on an understanding of process dynamics.

Unfortunately, almost nothing factual is generally available about process dynamics; what little is known concerns such characteristics as flows, temperatures, and pressures. Dynamic responses in terms of changes in materials composition is an almost completely unexplored area. However, this area is important, since the economics of refinery operation is intimately associated with the composition of what goes in and what comes out and is only secondarily related to the streams' temperatures. Increased emphasis—via test programs—is now being placed on measuring all significant streams compositions accurately and continuously and also on determining the dynamic interrelations between compositions and controllable variables.

Test procedures

The first step in process testing is to collect and examine daily operating records. This approach is attractive: it doesn't cost much and it gives a good quick look at the obvious problems. In exceptional cases, some process or operating improvement can be made from a simple examination.

In almost every case, however, the operating records will be inadequate for any detailed process study. Some records will be missing because no entry was made on the log sheet, a recorder pen was not inking, or a thermocouple was inoperative. Furthermore, chart-travel speeds of operating recorders are slow, extinguishing much of the process dynamic performance just in the width of the pen lines.

Supplementing regular records

In a practical test program, it will be necessary to supplement regular operating data by additional measurements. This step is influenced more by cost factors than by anything else. Supplemental measurements involve more cost than simply procuring the necessary instruments. For one thing, special instruments installation in an operating plant is costly because of safety precautions and standards.

Another high-cost item is increasing the frequency of process-stream sampling and analysis. Here, the greatest expense lies in the analyses, since their cost ranges from $1 to $200 per sample depending on stream complexity and the type of analysis. An alternate to taking discrete samples is the installation of analyzers which continuously record stream composition. Fully proven and reliable stream analyzers are generally limited to measuring such characteristics as viscosity, vapor pressure, dielectric constant, and refractive index. A promising analyzer for composition measurement of light hydrocarbons is the gas chromatograph. While a gas chromatograph can be bought for about $3,000, the installed-and-working cost in the refinery is between $5,000 and $15,000.

Supplementary test instrumentation will also be needed for measuring temperature, pressure, flow, and

Adding supplemental instruments and running special tests yields better test data.

The two sets of records contain test results to obtain dynamics information about a distillation tower. In both cases, the steam to the reboiler is raised from 21,000 to 24,000 pounds per hr at 9:30, held steady, and then dropped back to 21,000 pounds per hr at 10:30. The left set of curves represents the process responses recorded on regular plant meters having 1-in.-per-hr chart speeds; the right set contains the same responses, but recorded with special instruments in good working order and with 6-in.-per-hr chart speeds.

Slow chart speed

Point A. The operator introduces a step change by resetting the setpoint of the steam controller. Such a change might be introduced as part of a planned test or occur in normal process operation.

Point B. A typical example of what might happen in taking test data with regular operating instruments is this one where, unfortunately, the recorder pen stopped inking and consequently the time of dropping the steam is unknown.

Point C. Another typical difficulty is this case where the reflux flow recorder pen is so far down the square-root chart that nothing can be read with precision.

Point D. The bottoms product signal for some reason became noisy, making the record hard to read.

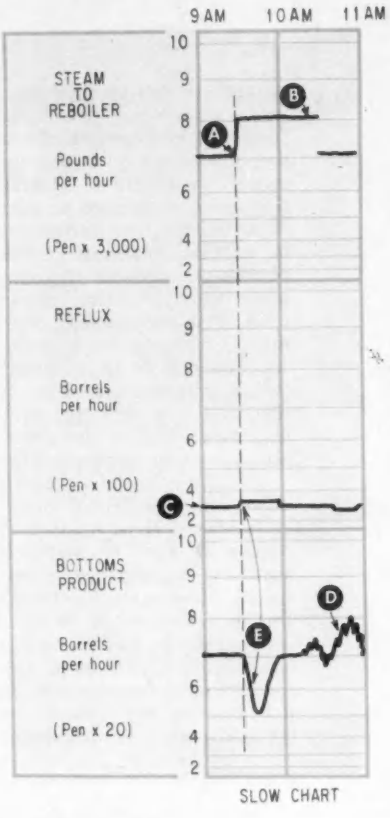
Point E. For dynamic response, on this slow chart it is almost impossible to see that the bottoms product flow responds immediately to the steam flow change while the reflux flow changes only after several minutes. Such information is easily readable on the fast chart.

Fast chart speed

Here, supplemental recorders are suitably adjusted as to time and scale, simplifying the gathering of dynamics data and improving precision.

Point E'. The shapes of the rise and fall of the reflux and bottoms products responses can now be interpreted by graphical techniques (Ref. 2 and 3) to give approximations to time constants as needed in dynamic analysis.

Point F. With the responses to the step change spread out, the lag (or dead time) between steam and reflux can be easily measured off the chart. Also note that lags 1 and 2 are not the same size, a form of nonlinearity disastrous to simple analysis. This nonlinearity was obscure on the slow-chart-speed record.



level. Some recorders will be indicating so far down their scale as to contribute little information; some chart speeds will be too slow. Such problems can be corrected at low cost with the plant operating.

A problem of greater magnitude is that of taking supplemental measurements at uninstrumented points. Adding a thermocouple well or an orifice plate means cutting a hole in a vessel or opening a pipe, and such installations can be made only when the plant is shut down and the container is empty and purged of explosive vapors. The cost of shutting down a productive plant is prohibitive; almost no test program can justify shutdown. A practical problem then arises, that of arranging for test-instrument installation during a scheduled (or next unscheduled) shutdown. This means that process test programs stretch out in time in a most unreasonable fashion. Tests must be planned, instruments ordered and received, and installations arranged months in advance. Then tests commence after the plant has come back on stream.

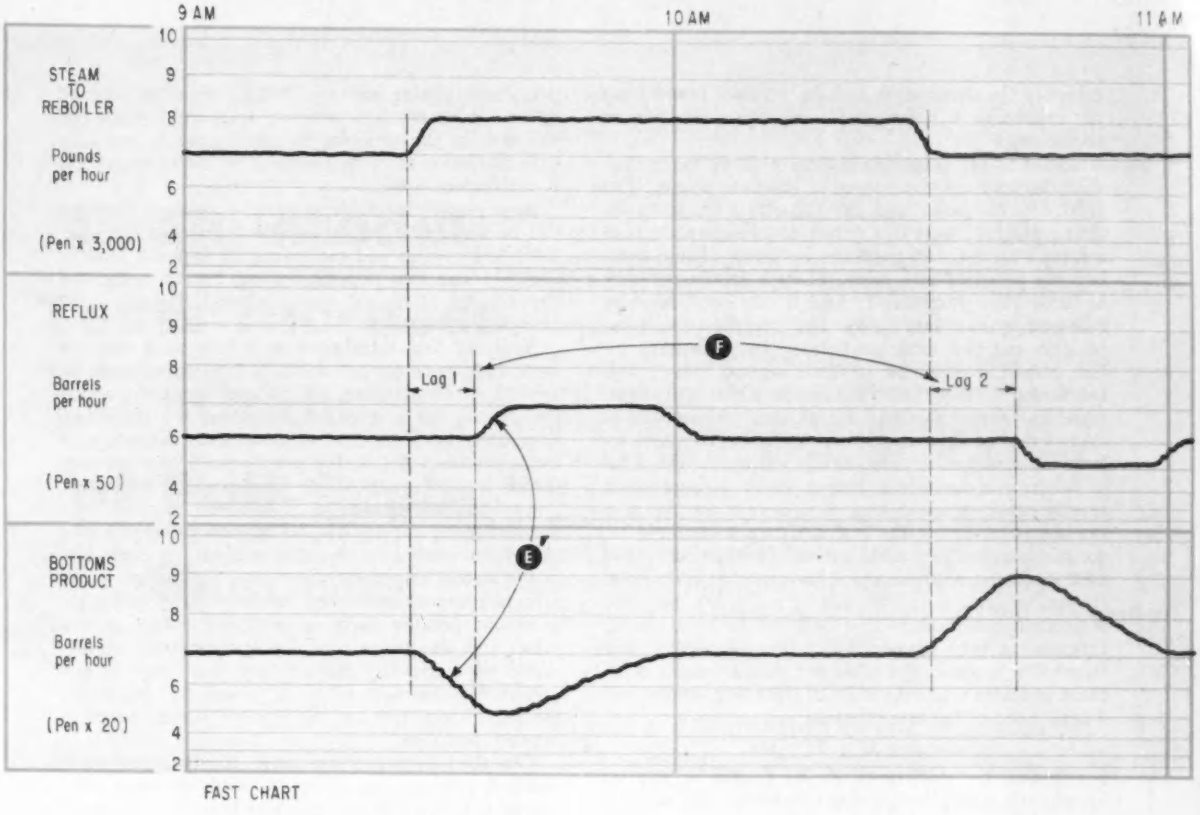
To circumvent some of these practical difficulties in process testing, Sun has added considerable instrumentation—to the previously mentioned distillation column—to run supplemental tests. Composition samples and temperatures can be measured on alternate trays, about 15 out of 30. With these supplemental measurements, it is possible, for instance, to run tests seeking a suitable control point along the column to anticipate changes in overhead product before they become significant. Here, the change at the control point must be large enough to be detected, and it also must be detected early enough (far enough down the column) to be valuable.

Special tests

Special tests must be resorted to if anything useful is to be learned about process dynamics or optimum operating conditions. The basic dynamics are obscured in regular, and even supplemental, records by the overwhelming desire of the operating department to keep everything running smoothly—because this is believed to be the way to make the most and best product and because upsets, desirable for analysis, are capable of getting out of hand. Consequently, with operating records, any logical determination of time constants or even cause-and-effect relationships is hopeless. Similarly, information about optimum operating conditions is seldom available from regular records. It is rare for an operating group to deliberately and systematically manipulate process variables to seek the most economic operating point.

Although special tests are essential to give practical answers to some questions about process operation, they can become extremely costly because of the possibility that off-spec material will be produced. Intentional upsets will be permitted only to the extent that the anticipated loss due to off-spec product can be justified by the value of the information gained. As an example, a common distillation tower processes 5,000 bpd. If the testing program degrades the products by an average of one cent per gallon, the daily cost of the test due to lost production is $2,000, not counting cost of instruments and testing.

Naturally, special testing will sometimes be authorized on the condition that disturbances introduced into the process do not exceed those that are in-



troduced by normal operation. This may be highly restrictive in some cases, but if the term "normal operation" is not too narrowly interpreted, some fairly wide dynamic excursions can be imposed and some broad areas of potential operation explored. Sometimes, an accidental or unusual upset will exceed in magnitude any permitted intentional upset. A certain amount of patience and good luck is needed to take advantage of such events, since it will be fortunate if the measuring and recording equipment is in place and functioning when an accidental upset occurs.

Typical of a planned special test are the responses shown in charts, above, to find cause-and-effect relationships and process dynamics. The description tells of some of the problems that arise when relying on regular plant recorders and the benefits gained by adding special instruments suited to the test purpose.

Special tests are always proposed for an operating plant with the hope that controlled conditions can be established. The hope is vain. Sometimes, all will go well for short periods; but plants are so complex and so subject to interference from everything else going on in the refinery that almost every real test will include noise of one sort or another. While it is possible and generally necessary to cope with noise effects in the analysis stage, it is desirable to minimize them in the measurement stage. Satisfactory minimization is a matter of intelligence, judgment, preparation, money, and good fortune.

Data analysis

The kind of analysis to be applied to test data depends on the purposes of the tests, the precedures employed, the analyst's ability, and the money available for analysis. Generally, some crude balance exists between money and effort expended on analysis and that spent on collecting the data. In short, the balance is obvious: do not ignore carefully collected, expensive data; do not apply elaborate and expensive mathematical tortures to a few carelessly recorded points. While poor or ill-advised analysis can work good data into a worthless mess, the best analysis cannot extract anything worthwhile out of bad data.

Static data

For analysis, static data—measured or calculated points—are plotted to facilitate interpolation between points, extrapolation beyond the measured region, or the smoothing or averaging of random data. If the plotted data present a somewhat scattered pattern (as they almost always do), and a smooth plotted curve is needed only for visual reference, a French curve and a shrewd eye will suffice.

On the other hand, if the data can be represented by a specific physical or chemical formula or if it is desired to represent the data as a polynominal, then a least-squares fit to the points can be obtained by one of the curve-fitting programs available for most digital computers. For example, if variable y is a function of some other variable x, these programs will give the values of the coefficients a, b, c, and d such that the expression:

$$y = a + bx + cx^2 + dx^3$$

best fits the data. Best means that the square root of the sum of the squares of the deviations between the y

values in the data points and the y values found from the expression is less than for any other selection of coefficients.

Useful fitting programs require nothing more than that the user list the values of his data points. The IBM 650 computer and the General Electric curve-fitting program meet this criterion. One simply fills in a form with the data points to be fitted. These numbers are punched into cards. Then a permanent deck of cards (the program) is loaded into the computer followed by the data cards. The computer, in turn, punches out new cards containing the coefficients for the best-fit polynomial of first, second, third, and fourth degree, as well as a tabulation of the dependent-variables values calculated for all four polynomials at every value of their dependent variable. The user selects the appropriate polynomial to represent the data.

When one variable is known to be a function of several other variables and it is desired to obtain a mathematical fit for the relevant data, a multiple regression program is available. Multiple regression works best when the relationship is known or at least some reasonable guess as to form can be made. For example, if product composition c is believed to be a simple function of feed composition f, temperature t, and steam flow s, one might make the measurements of all these variables under a variety of operating conditions. Then, if the correlating equation:

$$c = Z + Xf + Yt + Ws$$

is assumed, the coefficients Z, X, Y, and W can be found with multiple regression. This operation is allied to curve-fitting except that multiple regression is a surface-fitting operation.

Although it is often thought possible to arrive at a suitable fit with multiple regression simply by repeated trial of a number of arbitrary relationships, such efforts are generally frustrating and fruitless unless supported by some basic relationship arising from the physics or chemistry of the process.

Useful multiple regression programs put the least burden on the user and furnish him with the greatest flexibility in manipulating the relationship. Shell's RAP program for multiple regression can be carried out on the IBM 650. Here, the user selects the kind of equation to be used by inserting appropriate digits on the initiating forms. Then, he fills out additional forms with the values of data points. This information is converted to punched cards and loaded into the computer with the program deck. The calculated results are the coefficient values of the selected equation.

Dynamic data

No such tradition of systematic analysis is established for data taken deliberately to explore process dynamics. Visual examination of strip-chart records are almost always resorted to, yielding cause-and-effect relations and measures of dead time. This approach is far more fruitful when applied to controlled tests—such as using step or ramp changes—than when applied to regular operating data. Reswick and Goodman (Ref. 1) and a few others have described the use of correlation functions to determine system characteristics from regular operating records—and without applying artificial disturbances. However, there does not appear to be any great use of this technique in the petroleum refining industry. Its lack of success may be because it has not been seriously tried and because the variation in the variables of interest are so small in daily operation as to be obscured by recorded process or instrument noise.

In principle, a suitable analysis of dynamic response can be made by applying any of several forcing functions to a process and measuring its response (Ref. 2 and 3). The two popular forcing functions are the step change (transient response) and the sine wave (frequency response).

Applying the disturbance as a sine wave requires many tests since enough different frequencies must be applied in turn to cover the frequency region in which the process has a response. However, the individual amplitude and phase shift measurements made at each frequency need not be too precise since they are supported by measurements at neighboring frequencies.

Applying a step-change disturbance requires only one test since, in principle, all frequency-response data (the form needed for dynamic analysis) is embodied in the system response to just one step change. However, now the measurements must be made with great precision: because there is only one chance at the values and also because of the mathematical requirements of converting transient-response data to frequency-response data (Ref. 4, 5, and 6). Naturally, the step-change test can be repeated several times to improve precision.

The stream-composition time constants of some common processes are of the order of five hours (low frequency), although the hydrodynamic time constants are of the order of five minutes (higher frequency). Under these circumstances, while a hydrodynamic system frequency-response test might be run in a few hours, the same kind of testing for composition response would take a week. On the other hand, a step change applied to explore process composition dynamics will yield at least some information in one shift. Admittedly, the information obtained from a step change is not as complete or precise as that which a week of sine wave testing would yield, but there is a chance of keeping a process undisturbed by uncontrolled variables for a shift; there is almost no such chance if the test period is to be a week.

In the petroleum refining industry, the trend appears to be to use sine-wave signals to test valves, hydrodynamic control systems, and fast-acting components, and to use step signals to test process thermal and composition responses.

REFERENCES

1. *DETERMINATION OF SYSTEM CHARACTERISTICS FROM NORMAL OPERATING RECORDS*, T. P. Goodman and J. B. Reswick, "Transactions of ASME", February 1956, pp. 259-268.
2. *HOW TO RECKON BASIC PROCESS DYNAMICS*, L. M. Zoss, "Control Engineering", January 1956.
3. *ORGANIZED PROCESS TESTING*, E. W. James, "Control Engineering", September 1956.
4. *GET FREQUENCY RESPONSE FROM TRANSIENT DATA BY ADDING VECTORS*, A. R. Teasdale, Jr., "Control Engineering", October 1955.
5. *GET FREQUENCY RESPONSE FROM TRANSIENT DATA BY MACHINE COMPUTING*, J. B. Reynolds, Jr., "Control Engineering", October 1955.
6. *INTERCONVERTING FREQUENCY AND TRANSIENT RESPONSE*, H. H. Rosenbrock, "Control Engineering", July 1959.

Scale-Model Tests Increase Odds of Full-Scale Success

THE GIST: L. H. Baekeland expressed the main reason for model testing when he wrote: "Commit your blunders on a small scale and make your profits on a large scale." Experiments and modifications tried out on a small, relatively cheap unit that performs similarly to the full-scale system being studied can yield information that is impossible or impractical to obtain any other way. Scale models were used in the 1750's for studying ship contours and since have become a critical element in the design and study of ships, aircraft, chemical plants, and a variety of other processes and equipment. In model testing, the important point is to establish similarity criteria between the small and large-scale units, so that findings can be confidently applied to the large-scale system. The following highlights model testing and instrumentation in five fields and briefly touches on model theory.

BYRON K. LEDGERWOOD, *Control Engineering*

Models can be used in three ways: 1) as research tools, 2) as steps in the design process, and 3) as safe and cheap methods of studying possible improvements in an operating process. In almost every case, the major problems are designing a scale model that is truly representative of the large-scale system and accurately measuring the variables of interest while the model is under test. Achieving a truly representative model requires a knowledge of similarity principles and model theory. (See box next page.) Measuring the model variables often brings into play special instrumentation and control techniques. The basic problems are touched on below, and instrumentation is emphasized in the remainder of the article, covering model techniques in the fields of ships, flight vehicles, furnaces, rolling mills, and flow processes.

Model instrumentation and control

Smallness causes most of the problems in scale-model instrumentation. The difficulties arise in sensing the test variables and in transmitting data from the model to display or recording centers. Once the signals are clear of the immediate vicinity of the model, the problems are little different than those encountered in other test situations.

Thus the major sensing problems are as follows: 1) space to mount the transducers; 2) high impedance transducers that will not load the process; 3) transducer and data link mountings that do not interfere with model environment; and 4) accurate, sensitive and fast transducers that will accurately measure small quantities (such as flow) and rapid transients (in pressure, for example). In addition, there are many special sensing techniques for such things as spotting flow patterns and examining boundary layers.

Control systems find two basic uses in model systems: a) to maintain constant model environment or to change the environment in accordance with a fixed program (for instance, the control of flow, pressure, and temperature in a wind tunnel or the control of wave magnitude and frequency in a towing tank), and b) to vary the operating condition of the model (for instance, changing the attitude of a missile model in a tunnel, programming a pilot-plant through a series of operating conditions, or causing a research rocket to change course rapidly to study its dynamic characteristics).

In addition, models are often used to investigate process or equipment controllability and to check out new control systems. Studies have been made of model open-hearth furnaces, chemical pilot plants, model steel mills, model radar antennas, and many other processes and equipment for purposes of optimizing control. Cases are cited in this article and in the case study section of this issue.

Why use models?

The underlying reason for testing models is an economic one: it will probably be cheaper than the alternate possibilities. But many specific justifications exist within the gross reason of economic gain:

- Data obtained on a small-scale plant are usually more reliable and more accurate than data scaled up from the laboratory or derived by calculation or analog model from generalized correlations.
- Model modifications can be made relatively quickly and easily, so that widely different configurations can be tested, and time scales can often be changed either up or down.
- Accurate information on process adjustments and

A BRIEF LOOK AT MODEL THEORY

If the data obtained from experimenting with models are to be useful, it must be possible to extrapolate these data so that they are meaningful when applied to scaled-up versions of **similar** physical systems. The problem, therefore, is to make sure that the model and the large-scale system perform similarly, at least with respect to the phenomenon being investigated. Although the principles of similarity are often thought of in connection with the general concept of similar shapes (geometrical similarity), there are many additional similarity states of equal importance, i.e., mechanical, thermal, and chemical similarity. References 1 and 2 cover model theory and the principles of similarity in detail; the following briefly summarizes this material in order to provide background for this article.

Geometrical similarity is shape similarity, so that two bodies are geometrically similar if all points in one body are matched by corresponding points in the second body. The ratio of corresponding lengths in the two bodies is a constant known as the linear scale factor. It is also possible to have different scale factors along the three coordinate axes of the two bodies, resulting in distorted similarity. Note that if two bodies are related by a single linear scale factor n, the area scale factor is n^2 and the volume scale factor n^3. Because of this it may be necessary, for instance, to choose different scale factors for the length and diameter of a pipeline reactor, if overall process similarity is to be achieved. This then is a distorted model.

Mechanical similarity, which extends geometrical similarity to stationary or moving systems subjected to forces, is concerned with static, kinematic, and dynamic similarity. Thus, geometrically similar bodies subjected to constant stresses are also statically similar if their relative deformations are such that they remain geometrically similar. Then the ratio of corresponding displacements is equal to the linear scale factor.

If deformation is elastic, corresponding stresses must be in the ratio of the elastic moduli to achieve corresponding strains and the forces acting at corresponding points must be in the ratio of the elastic moduli times the square of the linear scale factor. If deformation is plastic, then forces must be in the ratio of yield stresses times the square of the linear scale ratio. Statically similar models are used to predict the elastic or plastic deformation of complicated members and structures, such as odd-shaped machinery housings and bridge structures.

Kinematic similarity, concerned with solid or fluid systems in motion, introduces the additional dimension of time. Thus, geometrically similar systems are kinematically similar if corresponding points in the two systems trace geometrically similar paths in corresponding intervals of time. The time scale factor may be greater or less than unity, so that the model may operate on a faster or slower time scale than the large-scale system. Kinematically similar models are of interest to almost all model experimenters, particularly those concerned with heat or mass transfer or chemical reactions.

Dynamic similarity includes the effect of forces that accelerate or retard moving masses in dynamic systems. In free-moving fluids or discrete particle systems, kinematic similarity implies dynamic similarity since the motions of the system are functions of applied forces. But in machines, where parts are constrained to follow fixed paths, kinematic similarity does not necessarily mean dynamic similarity. Not all of the forces accelerate the system; some of them may overcome frictional resistance, generate heat, etc. Thus, geometrically and kinematically similar systems are dynamically similar only when the ratios of all corresponding forces are equal.

The types of forces involved include gravitational, inertial, pressure, viscous, magnetic, etc., and it is the ratio of the magnitudes of these forces at corresponding points, expressed as dimensionless groups, that constitute the criteria of dynamic similarity. The difficulty is encountered when constant ratios must be maintained between several types of forces. Here, special techniques such as geometrical distortion may help to obtain dynamic similarity. Dynamic similarity is particularly important where the equipment is to be automatically controlled, and many model tests (such as those performed with missile and submarine models) are run to determine the dynamic characteristics of a large-scale unit from a dynamically similar model.

Thermal similarity introduces the dimension of temperature, as well as those of length, force, and time. Heat flows from one point to another by radiation, conduction, convection, and bulk movement of matter. In the first three, the rate of heat flow varies with absolute temperature and temperature difference, while the fourth heat transfer process depends on the flow pattern in the system. Again, there is the difficulty of having to satisfy several similarity criteria. Thermally similar models are important in the study of such things as chemical reactions and the conditions encounted by a missile during re-entry.

Chemical similarity covers chemically-reacting systems in which composition varies from point to point in continuous processes, and from instant to instant in batch processes. It is not necessary that the chemical compositions in the two similar systems be the same, but only that there be a fixed relationship between the point concentrations that determine similarity. Chemical concentration depends on temperature and bulk movement, so that all chemically similar systems must be geometrically and thermally similar, while moving systems must also be kinematically similar.

How to derive similarity criteria

To make use of similarity principles, dimensionless criteria must be established. Equivalence of these dimensionless groups in the model and large-scale systems result

control system settings, accumulated during model testing, reduce commercial-unit setup time.

- *When a new product is developed, the pilot plant can produce the samples needed for test and application study purposes.*
- *Model work permits parts of a system to be studied, often impossible with full-scale units.*
- *Even if absolute scale up is impossible, model testing is a powerful way to measure the relative performance of two different configurations.*

Testing the model

Models are tested in a similar way to operating processes, as discussed in the preceding two articles. Dynamic characteristics can be determined by applying sinusoidal, ramp, step, or some other special variety of forcing function. Steady-state tests using statistical techniques or some other forms of organized testing (such as Westinghouse OPCON) are useful for searching for optimum operating conditions and for getting the most information from the fewest tests.

SCALE-MODEL SHIPS

It was realized early that new ship configurations could be at least qualitatively evaluated by measuring the force required to tow a geometrical scale model through the water, and basic resistance testing hasn't changed much over the years. A scale model, varying in length from 3 to 30 ft is towed through still water by a carriage moving at different speeds. The model is constrained from yawing but is free to assume any vertical position dictated by the water forces. The tow force is exerted through a mechanical or electrical dynamometer, and records are kept of speed, trim, and resistance. The resulting curves of speed vs. resistance can be used to estimate horsepower requirements (Ref. 4).

Other standard tests run on ship models include: flow tests (where, for example, a model is held in a circulating water channel and dye is ejected from holes in the hull to study flow conditions and to determine the proper placement of appendages such as bilge

in similarity. There are two ways to derive these dimensionless groups: 1) dimensional analysis can be used if all of the variables that influence similarity are known, but the differential equation is not known; and 2) the dimensionless groups can be derived directly from the differential form if the differential equation is known but cannot be solved. Of course, if the differential equation is known and can be easily integrated there is probably no need for testing a model.

For example, the dimensionless groups that establish the similarity criteria for isothermal flow of a fluid are expressed by an equation of the form

$$\frac{F}{\rho v^2 L^2} = \phi\left(\frac{vL\rho}{\mu}, \frac{\rho v^2 L}{\sigma}, \frac{v^2}{Lg}\right) \quad (1)$$

This expression can be derived by dimensional analysis using the method of indices and starting with the seven variables that influence isothermal flow

Fluid velocity	v	Lt^{-1}
Linear dimension	L	L
Force	F	mLt^{-2}
Density	ρ	mL^{-3}
Viscosity	μ	$mL^{-1}t^{-1}$
Surface tension	σ	mt^{-2}
Acceleration of gravity	g	Lt^{-2}

or it can be derived from the fundamental Navier-Stokes differential equations for the isothermal flow of a Newtonian viscous fluid

$$\rho\frac{\partial u}{\partial t} + \rho\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\right) = \rho g\cos\alpha_x - \frac{\partial p}{\partial x} + \tfrac{1}{3}\mu\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}\right) + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) \quad (2)$$

The only difference in final form is that the term $\rho v^2 L/\sigma$ is left out if the groups are derived from the differential equation, since the Navier-Stokes relationship neglects the surface tension effects.

The groups established in Equation 1 are well known in fluid dynamics under the following names:

$F/\rho v^2 L^2$ = pressure coefficient (ratio of pressure to inertial forces)
$vL\rho/\mu$ = Reynolds number (ratio of inertial to viscous forces)
$\rho v^2 L/\delta$ = Weber group (ratio of inertial to surface tension forces)
v^2/Lg = Froude number (ratio of inertial to gravitational forces)

The prime advantage of deriving similarity criteria from differential equations rather than by dimensional analysis is that all significant variables are bound to be included. Sometimes when using dimensional analysis an important variable can be left out without realizing it.

Selecting the proper similarity criteria

Often the existence of several similarity criteria will result in conflicting requirements if exact correspondence is to be achieved between model and large-scale unit. For example, in ship model testing, the wave-making resistance of a ship depends on the Froude number, while the resistance from viscous friction depends on the Reynolds number (Ref. 4). To achieve equal Froude groups for the model and the full-scale ship, the model must be driven through the water at a much lower speed than the actual ship, the ratio being $1/n^3$. In contrast, for equal Reynolds numbers, the geometrically similar model must be driven at a speed equivalent to actual ship speed times the linear scale factor, a very high speed. Clearly these two requirements are incompatible.

One way around this problem is to run the model in a fluid that is much less viscous than water (1/125 if the linear scale factor is 25). While this is impractical in ship model testing, the approach demonstrates a technique that is useful in some cases. Actually in ship model work, the wave-making resistance is determined by model testing in a towing tank, while the frictional resistance of the model is calculated from empirical data. Then the total resistance is scaled up.

To avoid incompatibility, an attempt should always be made to construct the model experiment so there is one major similarity criterion. If this is impossible, then such artificial techniques can be resorted to as described above for ship testing, or distorted models might be used. For instance, if the heat transfer through a duct must be equivalent for both model and large-scale unit, then instead of using one linear scale factor the model must be distorted so that the surface area per unit volume is equal in both units. With large scale factors the duct becomes correspondingly short and care must be taken to avoid end effects.

Departures in theoretical similarity lead to scale effects that must be accounted for in scaling up and down. The scale model of a missile nose cone may be geometrically similar in overall shape, for example, but may differ in equivalent surface roughness. This is a scale effect that may seriously affect the thermal similiarity of the model and the actual missile cone when studying heating during re-entry.

Basic model theory will not give all the answers where it is impossible or impractical to operate a model at a value that would yield equality of the predominate similarity criteria (if for instance, the power required to drive a model paddle mixer was several times that required by the full-scale unit, Ref. 3). Under this condition it is possible to operate the model at some convenient value, predict the performance of the large-scale unit based on similarity criteria, and then extrapolate to the desired large-scale-unit operating conditions using a power-law relationship determined either experimentally or from empirical data. This is a powerful techniaue that has made possible a wide application of model-testing procedures.

The use of power-law relationships also points out the relative importance of various similarity criteria (Ref. 5). Thus, if one variable influences the results to the 4n power, and another to the n/4 power, the results of model testing will only be as good as the ability to calibrate the variable with the 4n exponent.

keels); propulsion experiments (where the model is self-propelled and records are made of thrust, torque, and revolutions, Figure 1, or where a propeller is run in open water to determine its characteristic curves); and steering and maneuvering tests (where the model runs free and rudder is actuated under radio control to study maneuverability, control surface configuration, rudder torque, and other variables).

In addition to the conventional ship model studies, many interesting and unusual tests are being performed. At Davidson Laboratory, Stevens Institute of Technology, various sea-keeping experiments are being conducted using a self-propelled remote-rudder-controlled model with six degrees of freedom (Ref. 6). Here, tests determine such things as influence of hull form, proportions, and freeboard on motions and general performance of a ship in a seaway; structural loads imposed by waves; and course-keeping qualities.

To limit the equipment that must be carried in the 5-ft model and to give a positive frame of reference, the carriage-supported mechanism of Figure 2A is used to measure the six motion components. Since no constraint should be placed on the model by the motion-sensing devices, this mechanism is servoed to keep up with the model. The longitudinal and lateral subcarriages are driven back and forth on the main carriage in accordance with the movement of potentiometer sensing elements on the parallelogram linkage. Sensing devices on the yaw, pitch, and roll bearings give the three rotational components, and devices on the heave plunger and the lateral and longitudinal carriages give the translatory motions (relative to the main carriage).

In one test, this equipment is being used to study the sea-keeping ability of ship models in regular and irregular waves that are generated by a wavemaker, Figure 2B. Where tests are to be performed with the model heading obliquely into irregular waves an autopilot is to be added, since it is difficult to maintain an accurate course by remote steering.

In another test at Davidson Laboratory, the effect of speed and hull fullness on hull bending moments

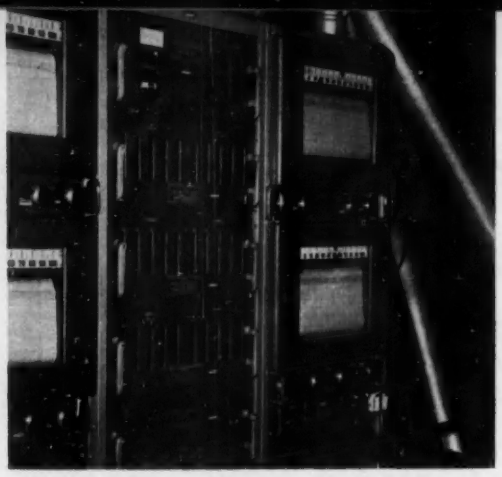
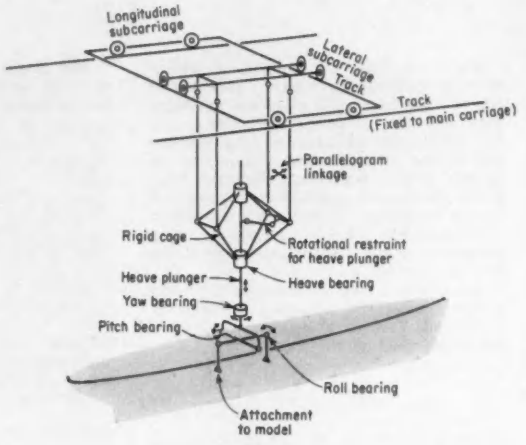


FIG. 1. Revolution-speed-time recorder used for propulsion experiments at David Taylor Model Basin. Equipment rides on tow carriage and continuously displays propeller thrust and torque during run.



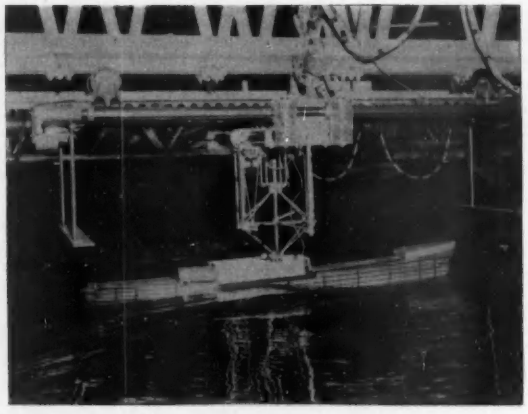


FIG. 2. A—Mechanism senses motions on six-degree-of-freedom model without constraining model movement. B—Model under test for sea-keeping ability in regular waves uses parallelogram linkage shown in A.

in various types of waves is being investigated (Ref. 7). Here, the models were cut amidships, joined with a flexure beam, and the point sealed with thin rubber. Figure 3 shows the bending moment dynamometer: a plastic-sealed linear differential transformer senses the hogging and sagging moments as the flexure beam deflects in reaction to the water forces.

The hydrodynamic-stability derivatives of deeply submerged models can be determined with the planar motion mechanism shown in Figure 4. Internal force balances sense the force components at each supporting strut. Static forces and moments associated with hull angles are obtained by remotely rotating the tilt table carrying the entire model-strut system. The data are displayed by digital indicators and automatically tabulated by an electric typewriter.

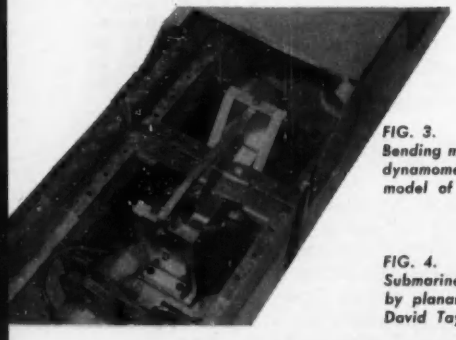
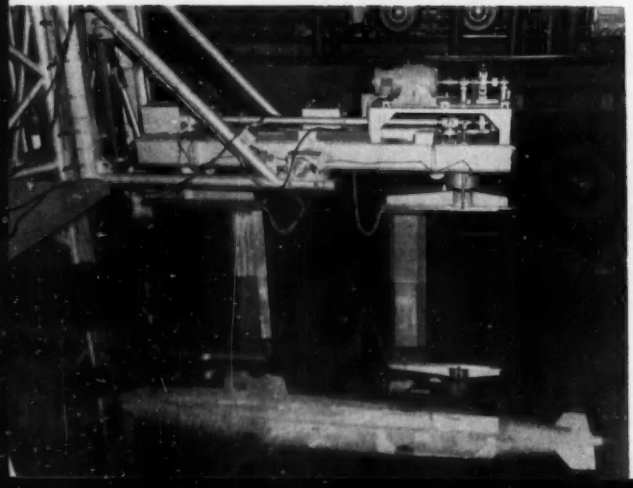


FIG. 3. Bending moment dynamometer installed in model of T2 tanker.

FIG. 4. Submarine model ready for testing by planar motion mechanism at David Taylor Model Basin.



Dynamic forces and moments are determined by applying a sinusoidal forcing function to the struts—first in unison and then in phase opposing. The signals are electronically resolved, rectified, integrated, and recorded, saving data reduction time.

SCALE-MODEL FLIGHT VEHICLES

Flight vehicle models are tested to determine the forces, moments, pressures, and temperatures to which the full-scale vehicle will be subjected as it travels through air or space. There are two ways of performing these tests: 1) the model can be supported in a wind tunnel and the air caused to flow by it, or 2) a test rocket or aircraft can be flown as a free body. When a model is supported in a tunnel, forces and moments can be measured by devices such as strain gages and displacement transducers. But a free-flying model has no fixed frame of reference, and gyros and accelerometers are necessary to sense the forces and moments.

Free-flying models

Typical free-flying model testing is done at National Aeronautics and Space Administration's Pilotless Air-

craft Research Station, Wallops Island, Virginia. The vehicles flown at this installation are engineered at NASA's Langley Research Center, shipped to Wallops Island, and flown. Telemetered and tracking data are then returned to Langley for analysis.

A five-stage research rocket flown by NASA at Wallops Island to speeds in excess of 11,000 mph (Mach 16) is shown in Figure 5. The purpose: to obtain information about aerodynamic heating and other characteristics of ballistic missiles and space vehicles designed for piloted flight. Most of the models flown at Wallops Island do not represent any specific airplane, missile, or space vehicle; they are usually research shapes, often of unconventional design.

Test flights are used to determine such things as heat transfer vs. Mach number, lift and drag coefficients, effects of fin shape on missile stability, cross coupling between various rotational and translatory axes, and vehicle dynamic characteristics. A test vehicle to yield information on nose cone heat transfer, stability, and drag vs. Mach number might be instrumented as shown in Figure 6: a) flow directional or pressure balancing instrument in nose measures angle of attack; b) multiple thermocouples in nose cone sense temperature distribution and change, later differentiated to determine heat transfer coefficient; c) total head, necessary for computing Mach number, is sensed a fixed number of shock waves aft of missile nose; d) three translatory accelerometers sense acceleration in normal, longitudinal, and transverse directions; e) angular accelerometers and velocity sensors sense acceleration and velocity around rotational axes; and f) thermocouple signals are sampled by commutator switch, conditioned for transmission, mixed with signals from other transducers, and telemetered to ground station.

Mach number is a function of total pressure head and static head. Total head can be sensed on the vehicle, but errors are usually introduced in the static head measurement. For this reason, the missile is usually tracked by radar to determine altitude vs. time, and then radiosonde equipment (balloon with sensing devices and transmitter) is sent up to determine pressure vs. altitude. These data give pressure vs. time for the missile flight, which when combined with total head measurements made during flight permits calculation of Mach number.

Test rocket dynamic characteristics are obtained by applying a momentary step change in position to the control surfaces or by applying a step disturbance via a pulse rocket. In the first case, a time-programmed system diverts the control surfaces momentarily and the dynamic characteristics are determined by studying the oscillation and decay of the transient response. In the second scheme, a pulse rocket aimed at right angles to missile path and located some distance from the center of gravity is fired and the response measured as the missile returns to course.

Tunnel models

Tunnel tests are run with the model supported, so that the forces and moments measured by accelerometers in free-flying models can be measured by strain-gage bridges and other types of force measuring devices in supported models. Tunnel testing has the advantage that individual portions of a vehicle can be tested, and unconventional configurations can be checked out without danger of model destruction.

A typical missile model developed for the Convair High Speed Wind Tunnel in San Diego, Calif., is instrumented to measure: 1) total lift force, pitching moment, side force, yawing moment, and rolling moment; 2) hinge moments on three control surfaces and normal force and bending moment on a fourth panel; 3) static pressure at 68 orifices on the body surface; and 4) model pitch and roll attitude. Here, all instrumentation with the exception of that required for item 4 is contained within a model 45 in. long and 3 in. in diameter. The model is to be tested at various Mach numbers and roll attitudes and with variations in shape and control surface deflection.

At the Convair tunnel, raw data are recorded on magnetic tape for later transfer to punched cards and processing by general-purpose digital computers. The recording equipment is paralleled by an analog computer for rapid computation of "quick-look" data. Six force components plus an angle can be computed. Display is by three analog plotters (Ref. 9).

A further appreciation of tunnel test procedures can be obtained by examining two types of experiments performed in the Unitary Plan Supersonic Wind Tunnel at NASA's Langley Research Center.

Pressure measurement—Pressure distribution over the model surface determines the basic loads on the vehicle. Up to 250 to 300 pressure measurements are made in a 36-in. model. The orifices have negligible effect on airflow over the surface, the only problem being that when tests are run at high Mach numbers with low tunnel pressure the orifices have to be large enough to pass the air with small lag times. When dynamic pressure data are being accumulated, the pressure transducers are usually installed within the model and the information transmitted electrically through the model support. Devices such as a scanner valve that can sense 45 pressures and convert them into electrical signals are particularly useful in this application.

Flutter speed tests—These are made with a dynamically similar model, so that flexibility, center of gravity and moment of inertia must bear known relationships to those of the actual vehicle. The tunnel is usually run at constant Mach number with increasing pressure until flutter starts. This test condition is similar to that encountered by a vehicle diving from a high altitude at constant Mach number. Both control surface and panel flutter are investigated using strain and displacement gages supplemented by high-speed photography.

Interesting tests are performed in a vertical tunnel at Langley. Here, for example, a dynamically similar model might be spun into the airstream (free-flying) and its spin recovery capabilities studied. Oscillation periods can be determined directly, and various control motions can be triggered to study their effect on performance. Pilot spin recovery programs are developed in this manner, and dangerous flight attitudes that are to be avoided in flight can be spotted. In this tunnel information is acquired mainly by observation and high-speed photography.

The tremendous amount of information accumu-

FIG. 5. *Five-stage research rocket fired from Wallops Island, Virginia.*

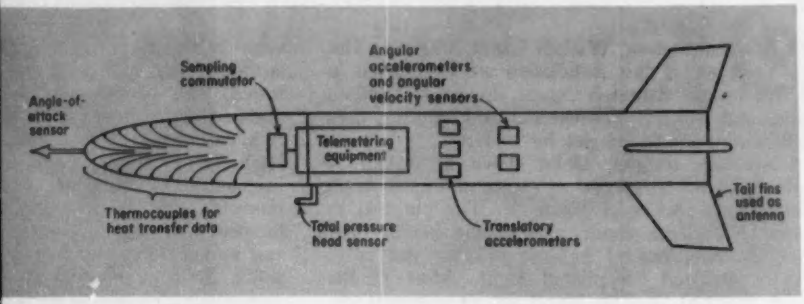


FIG. 6. *Typical instrumentation in a research rocket.*

lated during wind tunnel testing presents a difficult data acquisition and processing job. Recently, Langley purchased two Beckman 210 systems to speed data reduction. The smaller of these two systems can handle 20 digital inputs and 100 analog inputs. Signals are transmitted from as far as 2,000 ft away to high-quality differential amplifiers whose output is digitized and recorded on an IBM 727 tape unit or printed out on demand on an electric typewriter. Patchboard connections make it possible to handle many different tunnels and test facilities with the one data system.

SCALE-MODEL FURNACES

Designers and users of combustion chambers and furnaces have made wide use of models to acquire data for new designs and to study the operation and modification of existing furnaces. Both hot models to obtain heat transfer data and cold models to show gas flow conditions have helped the furnace designer in improving product quality, reducing fuel requirements, and increasing furnace life. In Reference 10, M. W. Thring carefully reviews much of the work done in this area. The following hits the high spots to show the usefulness of the approach.

Both air and water cold models have their place. Because of the relative kinematic viscosities of the furnace gas and the test fluid, similarity is achieved when an air model is operated at about the same flow velocity as the full-scale unit and when a water model is operated at considerably lower velocities. As a result of this difference in test fluid velocities, water models are preferable for studying visual flow patterns, while air models are best for pitot tube surveys of flow pattern and velocity distribution, for observing the impingement of fluid borne particles on walls and baffles, and for studying gas stream mixing. Air models are easier to construct and modify than water models but are less satisfactory for visual observation and require the removal of large volumes of smoke.

Several techniques are used to enable flow pattern visualization in water models: pulses of dye can be introduced in the flow, fine air bubbles can be injected, aluminum particles can be suspended in the liquid, and two liquids of different density can be used to study the distribution of hot and cold furnace gases. Water models have been used to investigate flow patterns in open-hearth furnaces, side-blown Bessemer converters (Figure 7), gas turbine combustion chambers, and many other gas flow processes.

Similar methods are used for studying air models: the distribution of a tracer gas added to the air can be checked by sampling throughout the model with an infra-red analyzer; dust can be added to the airstream; and flame and gas impingement can be investigated by coating the surface under study with a sticky substance and noting the accumulation of dust.

Hot models are used primarily to investigate heat transfer effects. A good example is the 1/12 scale model of a 300-ton open-hearth furnace installed at the US Steel South Works, Figure 8. Because of the necessity of separating combustion effects from heat generating effects in the chemistry of making steel, a rectangular tank takes the place of the metallurgical charge. Water flows through this tank and absorbs heat. This measurable heat flow corresponds to the heat absorbed by steel in a commercial furnace.

The high temperatures attained in open-hearth furnaces impose severe conditions on the refractory roof. The model is equipped with many thermocouples to investigate this temperature distribution pattern. A variety of instruments and controls, permits any combustion factor to be changed independently and the results studied—not possible in a commercial unit.

SCALE-MODEL ROLLING MILLS

Experimental mills, both small model mills and laboratory mills approaching the size of a commercial unit, have been used to study basic metal rolling phenomena, new mill configurations, and new types of control systems. References 12 and 13 discuss tests performed to study two different mill performance characteristics and the changes needed to achieve improved control.

In Reference 12, H. Gill investigates the effect of drive-motor droop on interstand tension using the model mill shown in Figure 9. The model is designed so that both the mechanical stiffness of the stands and the drive motor speed-torque characteristics can be varied at will. Only model design and

FIG. 7. Water model shows flow of gases parallel to tuyeres in side-blown converter. (Courtesy of "Coke and Gas")

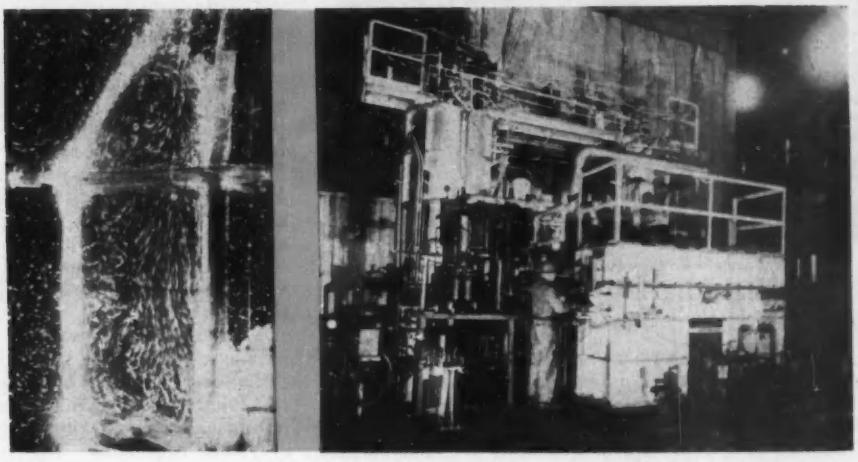


FIG. 8. Model open-hearth furnace at US Steel's South Works.

instrumentation will be touched on here; the referenced material gives all the details.

With strip thickness, speed, and roll diameter scaled down by a factor x and strip width by xy, roll force is reduced by a factor x^2y, main drive power by x^2y, and stand rigidity by xy. The extra scaling factor on width, y, reduces power requirements and simplifies mill design. The following table (taken directly from Ref. 12) summarizes the scaling operation:

	Full-size mill	Model (x = 9, y = 18)
Work roll diam, in.	21	2⅓ (1-in. face)
Initial strip thickness, in.	0.1	0.01
Strip width, in.	72	0.5
Main drive power, hp	12,000	1
Stand rigidity, tons/in.	12,000	variable about 75
Finishing strip speed, ft/min	800-1,200	15 (out of scale)

The model is designed so that stand stiffness can be altered by changing the height at which the two pivoted lever arms apply the load. The mill is powered by seven 1/7-hp electronically-controlled split-field dc servomotors, driving through reduction gears that give the basic finishing speed of 15 ft/min. Although considerably lower than the scaled down value, this low speed permits transients in load, torque, and tension to be easily followed. Speed control is by tachometer generator, and variable speed regulation (droop) is achieved by opposing the speed reference signal with a signal proportional to torque.

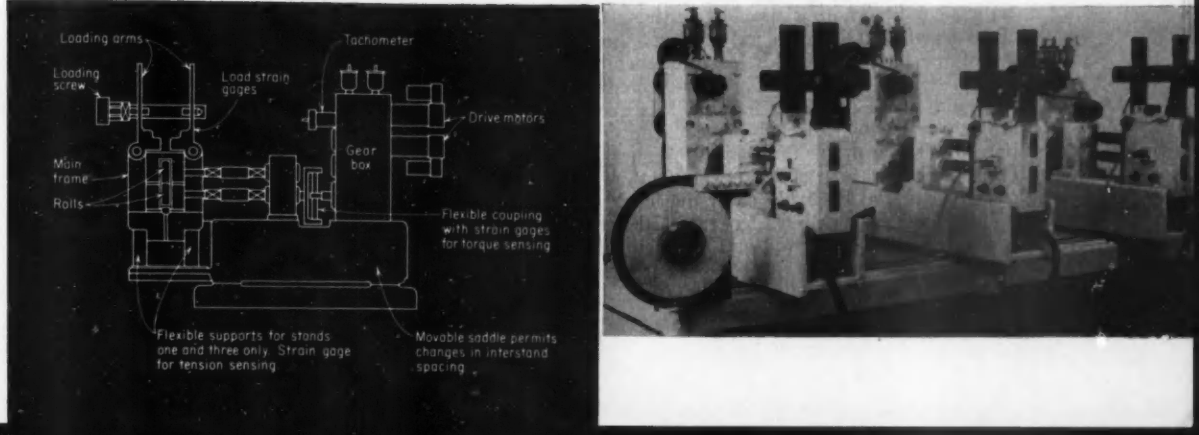
Roll force is measured with strain gages at the base of each loading arm, interstand tension is sensed by strain gages that measure the inward pull on stands one and three, and torque is sensed by strain gages on flexible torque arms between gear and pinion boxes (see Figure 9). Strip thickness is measured by an inductive displacement transducer in contact with the strip (satisfactory for the low speeds involved). A six-pen recorder is used to record the variables of interest in a particular test.

In Reference 13, G. E. Kennedy and F. Slamar discuss their investigation of turn-up and turn-down in hot rolling on a 30-in., two-high pinion drive experimental rolling mill at US Steel's Applied Research Laboratory. Although a much larger mill than that used by Gill, it still offers the benefits of mill and control system flexibility, controlled conditions, and extensive instrumentation. Test variations included: symmetrical and unsymmetrical rolls for structural shapes, load-regulated and speed-regulated twin drive tests, and various slab initial and entry conditions.

SCALE-MODEL FLOW PROCESSES

As in the other forms of model testing, pilot plants are used as a step in the design process and for the investigation of possible modifications to existing

FIG. 9. Gill's three-stand model rolling mill.



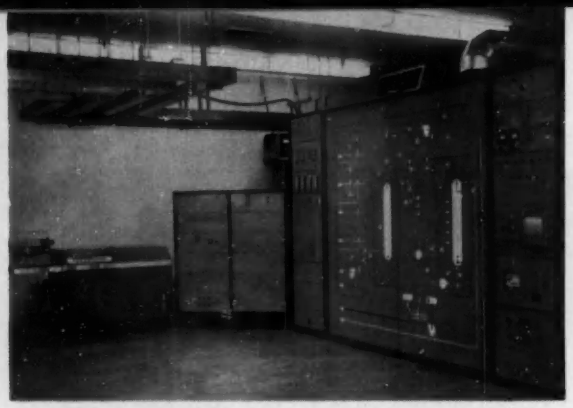


FIG. 10. Computer-controlled pilot plant built by Consolidated Electrodynamics Corp. for Esso Research and Engineering Co.

plants. But there are two aspects of pilot plant usage that are not found in other model work: 1) sometimes lack of confidence in similarity criteria and scale up will mean that several stages of pilot plants will be built (for example, prepilot scale, conventional pilot plant, and semi-commercial plant), and 2) often the need for product for the purposes of application testing and marketing studies is satisfied by the product output from a pilot plant. No attempt will be made here to cover the complex topic of pilot plant design and scale up, rather the reader is referred to References 1, 3, 14, and 15.

The high cost of pilot plant construction and operation has caused work in two directions: the design of more efficient experiments so that more information can be accumulated with fewer tests and the design of smaller and faster pilot plants with improved instrumentation and control to cut down on manpower requirements and speed testing in general.

An efficient test is one that gives the required information with minimum manipulation of variables, whether the variable be a temperature, input product composition, or mechanical modification of the plant. Pilot plant users have devoted much attention to evolutionary operation testing techniques such as proposed by Box and Hunter, including statistical analysis and factorial or partial factorial designs. These techniques are particularly useful in pilot plant testing because of the high costs involved and because they help to lay out a test program that will cover all eventualities and prevent important but unforeseen effects from slipping by unnoticed.

Considerable attention has been devoted to improved instrumentation and controls for pilot plants: small-scale primary elements (such as accurate automatic weighing devices), miniature flow control valves, and other types of special control devices have become available. These are useful in two ways: 1) for the investigation of new control schemes and 2) for automatically sequencing the plant through a fixed series of operating conditions, thus speeding testing.

W. Priestley of Esso Research and Engineering is an advocate of the latter approach. He recommends:

- that a pilot plant be completely instrumented and controlled and that a computer be used to sequence the plant through a preselected range of operating conditions. Automatic operation means high speed and the possibility of unattended testing.
- that extensive use be made of on-line analytical instruments. This is much faster than laboratory analysis and prevents errors resulting from such things as condensation of product in gas-vapor processes during the trip to the lab, and the absorption of trace components by the transport container.
- that all signal conditioning and computation of raw data be done directly in the programming computer, yielding on-the-spot information about product composition and process results.
- that smaller, faster pilot plants that don't take so long to reach steady state be used, since on-line analytical instruments will operate with very small amounts of product. In fact, it may not be necessary to stop the process at all; instead, it could be slowly varied over the range in question and the variables measured on the fly.

Much of this philosophy is included in the computer-controlled pilot plant described in Reference 15 and soon to be delivered to Esso Research, Figure 10. Priestley feels that this equipment will increase testing accuracy and considerably reduce testing time.

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REFERENCES

1. *PILOT PLANTS, MODELS, and SCALE-UP METHODS IN CHEMICAL ENGINEERING*, R. E. Johnstone and M. W. Thring, McGraw-Hill Book Co., Inc., New York, 1957.
2. *DIMENSIONAL ANALYSIS AND THEORY OF MODELS*, H. L. Langhaar, John Wiley & Sons, Inc., New York, 1951.
3. *THE SCALING-UP OF CHEMICAL PLANT AND PROCESSES—INTRODUCTORY PAPER*, R. E. Johnstone and M. W. Thring, "Proceedings of the Joint Symposium on the Scaling-Up of Chemical Plant and Processes", London, 1957.
4. *THE FUNDAMENTALS OF SHIP MODEL TESTING*, F. H. Todd, presented at New England Section, Society of Naval Architects and Marine Engineers, April 1951.
5. *SCALE-UP ASPECTS OF THE PILOT PLANT*, D. Q. Kern, presented at AIChE Symposium on Laboratory and Pilot Plant Techniques, March 1959.
6. *MODEL TESTS IN THREE-DIMENSIONS AT STEVENS*, E. Numata, Second Seminar on Ship Behavior at Sea, Stevens Institute of Technology, June 1958.
7. *EFFECT OF SPEED AND FULLNESS ON HULL BENDING MOMENTS IN WAVES*, J. F. Dalzell, Davidson Lab., Stevens Institute of Technology, February 1959.
8. *NEW RESEARCH RESOURCES AT THE DAVID TAYLOR MODEL BASIN*, E. A. Wright, published by David Taylor Model Basin, January 1959.
9. *THE CONVAIR HIGH SPEED WIND TUNNEL*, D. P. Cumming and C. R. Olden, Convair, San Diego, Report HST-TN-57-2, May 1957.
10. *IMPROVING FURNACE PERFORMANCE BY MODEL INVESTIGATION*, M. Thring, "Coke & Gas", April 1955.
11. *FUEL TECHNOLOGY AT UNIV. OF SHEFFIELD*, M. W. Thring, "Journal of the Institute of Fuel", October 1955.
12. *AN EXPERIMENTAL APPROACH TO SOME CONTROL PROBLEMS OF MULTI-STAND ROLLING MILLS*, H. Gill, "Transactions of the Society of Instrument Technology", delivered December 1958.
13. *TURN-UP AND TURN-DOWN IN HOT ROLLING*, G. E. Kennedy, F. Slamar, "Iron & Steel Engineer", March 1958.
14. *PILOT PLANTS IN PROCESS TECHNOLOGY*, E. L. Clark, "Chemical Engineering", in four parts—April 21, June 2, July 28, and October 6, 1958.
15. *EQUIPMENT MAKE-UP OF A COMPUTER-CONTROLLED PILOT PLANT*, E. C. Boycks, C. K. Hines, and W. Priestley, Jr., delivered at AIChE Atlantic City Meeting, March 1959.

Add Flexibility to Testing: Test an Analog Simulation

THE GIST: Simulation is unquestionably the most powerful engineering tool yet devised for convenient testing of complex systems. An analog computer simulation, for example, reduces the problem of test measurement and recording to simple connection of ordinary laboratory instruments. And computers are designed to make the changing of simulated process values easy and fast, thus increasing flexibility of tests. Simulator testing is more flexible, too, because real product need not be wasted nor equipment or personnel endangered to try new ideas. Even time itself can be "slowed down" or "speeded up". New techniques practical only on simulations add to conventional tests the dimension of automatic optimization of system parameters.

E. J. KOMPASS, Control Engineering

Analog simulation is one of the most powerful tools available to the engineer for testing a design before or after system construction. For system testing, an entire problem can be simulated—the process and the control system under test. Such simulations can include only the overall dynamic characteristics of subsystems, as for checking the theoretical effects of a synthesized controller transfer function on system stability; or they can be of the physical components themselves, part by part. The latter method permits variation of component parameters to determine their effects on component behavior and their criticality with respect to system operation.

Component-by-component simulation also makes another valuable technique easier. As components and subsystem groupings reach breadboard and finalized stages of construction, they can be connected in place of their simulations to the rest of the simulated system and tested for operation under conditions closely approximating the real ones that must be met. Unusual environments may even be reproduced in the final stages. A good example of the limits to which such thinking has been carried successfully is detailed in the article on page 194 of this issue.

Analog simulations are also useful after actual systems are built and operating. Thus, the effects of changes proposed on a producing chemical plant can be tested without the expensive loss of product that might result from testing the real plant. In these cases, normal operating records from the real plant are used to verify the correctness of the simulation before making the proposed changes.

This same approach is brought a step farther in post-flight missile simulations for failure analysis. In these post-mortem analyses, the cause of failure has often been traced to specific components by simulating the suspected defect and "re-running" the flight. Comparison of the simulated behavior with records of the actual flight then check the suspected cause.

A simulator can be used, too, to learn more about the steady-state characteristics of real processes too complex for complete theoretical description. Starting with a simulation of the theoretical relationships in a chemical reactor, for example, these can be modified or manipulated until the input-output levels after transients settle out agree satisfactorily with those on the real reactor over a stated range of steady-state conditions. The simulation can then be literally taken apart and studied in a way the reactor never could, and much learned about the real factors operating in the process. There are no formalized methods for using a computer in this fashion—good engineering intuition produces the steady-state match from which better knowledge of the process results.

An interesting trend is developing to "insure" the operation of complex systems by requiring successful simulations before letting final construction contracts. As an example, the high-power (1,500-kw peaks), high-response drives for a rotating bridge that propells ship models around a new circular tank at David Taylor Model Basin were contracted only after Allis-Chalmers had simulated them successfully. Modified mill motors were needed to fill the bill.

Reasons for using analogs

There are many reasons for using analog simulations of systems and parts of systems while testing for design or improvement, and particularly for using the electronic analog computer. The reasons are all practical, and the advantages are tangible. They are:

• **Flexibility**—parameters that may be very difficult or expensive to change in real equipment or a proposed process can usually be varied by the simple turn of a dial in a well designed analog circuit. Optimum values for mechanical inertias or the size of hydraulic ac-

cumulators, for example, can be determined very quickly in this manner.

• **Time scaling**—time is invariable in the real world, but it, too, can be scaled in a simulated one. Thus, actions that are too fast to follow in a real time test can be slowed so that data can be captured, and process effects that take hours or even days to show up can be speeded to save testing time. Time scales are changed in an analog simulation simply by changing all time constants by the same factor.

• **Compatibility of indicators**—many commercial recorders and indicators can operate directly from the outputs of commercially-available analog computers, and this avoids the otherwise necessary matching of characteristics (physical, electrical, etc.) when measuring devices are applied to real equipment. This advantage may properly be sacrificed as real equipment is tied into a simulation in the latter stages of a design.

• **Ease of testing compensating devices**—variable nonlinear signal-shaping devices can be introduced into a simulated system very easily to test theorized effects on system stability or to linearize an output presentation for more convenient analysis. When a satisfactory stabilizing function is found it can be synthesized in its simplest fixed component form for use in the real system. A number of variable function generators are commercially available for use with analog computers, and simple nonlinear functions can be simulated with computer relays and amplifiers (Ref. 1).

• **Ease of applying forcing signals**—the high input impedances and variable gains available at various points throughout an analog computer solution permit simple connection of all kinds of function generators for application of forcing signals ranging from constants, through variable-frequency sinusoids and other periodic functions, to random noise disturbances and even one-shot special functions such as the doublet impulse. A very wide range of time varying functions are available from commercial generators, and special functions such as typical operator commands can even be tape-recorded for input to the computer. An analog simulation can thus be run through a typical operating period for the real system or subjected to a series of mathematically precise command signals for determination of stability and frequency response.

• **Simulator availability**—the mere fact that an analog computer is immediately available can often be a real economic advantage when complicated systems are being designed. The possibility of testing a new idea for which no real equipment yet exists permits development to go ahead at the fastest pace with no worry about subsequent failure of an untested premise. Analog simulation in this way extends the very practical idea of system testing during development right back to the basic system concepts themselves.

Some theory and practice

Different approaches are possible in designing analog simulations. The first involves synthesizing circuits (electronic analogs are assumed here for convenience) from the simultaneous equations that describe the static and dynamic relationships in a system. Such a simulation is illustrated by Figure 1.

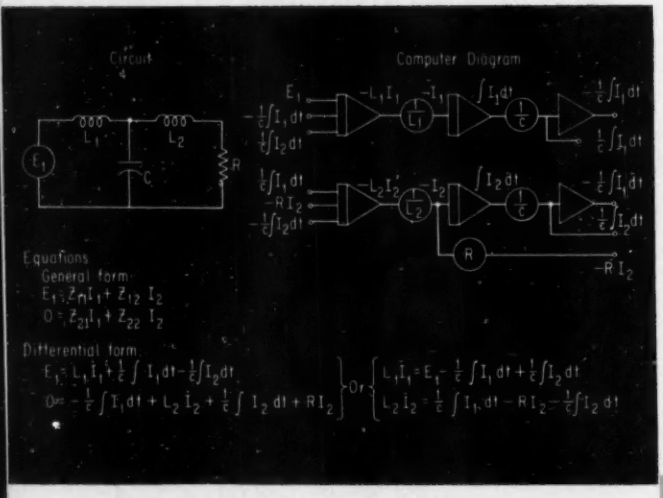


FIG. 1. Simulation of circuit equations leads to incorrect computer diagram at right. Note four storage elements in simulator, only three in original circuit.

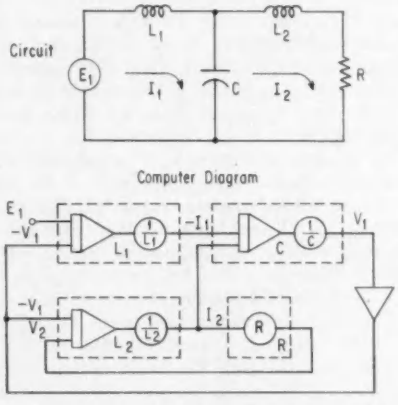


FIG. 3. Using simulators for components results in computer diagram with correct number of storage elements. No system equations need be written.

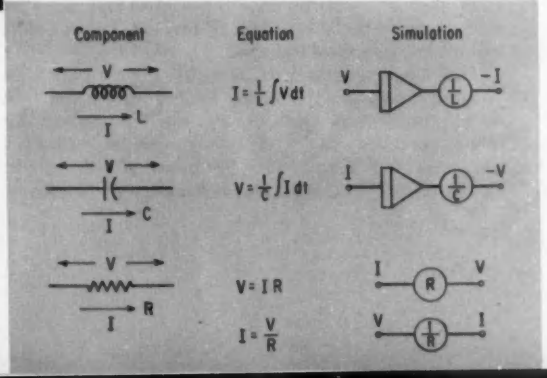


FIG. 2. Components can be simulated individually from their own equations.

which is reproduced from Reference 2. In this example, the computer diagram represents the network loop equations for the electrical circuit to be simulated. Note that the equations have been arranged so that no differentiating operations are actually required in the simulation (this is a practical step that is always observed when possible, since differentiation accentuates natural circuit noise and can mask desired results). But more important, note that no combination of computer elements uniquely represents the components of the original circuit. This simulation even has four energy storage elements while the original circuit has only three, which means that it is not truly analogous to the original. The circuit would theoretically produce correct time behavior if all the integrators were perfect—but will not with practical equipment.

In the same article (Ref. 2), Larrowe described a technique for direct simulation of any system, such that the resulting computer circuit will contain the correct number of storage elements *and* a unique combination of computer elements for each component in the original system. Larrowe's technique is based simply on synthesis of the *components'* time equations and interconnection of these, rather than solution of system time equations. Figure 2 shows the component equations and computer diagrams for the components in the original circuit of Figure 1. Figure 3 is the computer solution for the original circuit as produced by Larrowe's method.

As mentioned earlier, the component-by-component simulation of the direct method has the advantage of simplifying the determination of a component's effect on system performance. The value of any component in the original circuit of Figure 3, for example, can be changed by merely turning the potentiometer concerned, and the effect of the change observed.

Still another method of constructing computer circuits has been described by Follinger and Seifert (Ref. 3), which is a kind of combination of the two methods just described. The authors recommend starting with the equations for the system components, as does Larrowe, but use "structural blocks" that represent mathematical-computer operations and do not necessarily produce a circuit with a unique component-by-component simulation, though it may require somewhat less computer equipment than the direct method. To save computing equipment, certain subsystems whose effects are well-understood are simulated by their input-output relationships only, in any case.

The foregoing descriptions of simulation approaches have assumed the use of electronic analogs because they are most common. But the time behavior of the example circuit could be simulated just as precisely, if less conveniently, by mechanical, hydraulic, or even thermal systems. The example cited would be ridiculously complicated, of course. But consider the possible advantages of using a mechanical analog for the hydraulic servo control system on a reduced-scale aircraft model built for wind-tunnel tests, in which control power requirements are relatively lower than the original. The mechanical analog could be considerably less expensive than a scaled hydraulic system, and might even avoid certain scaling problems peculiar to fluid systems (see p. 147, this issue).

As another example, certain kinds of systems, like

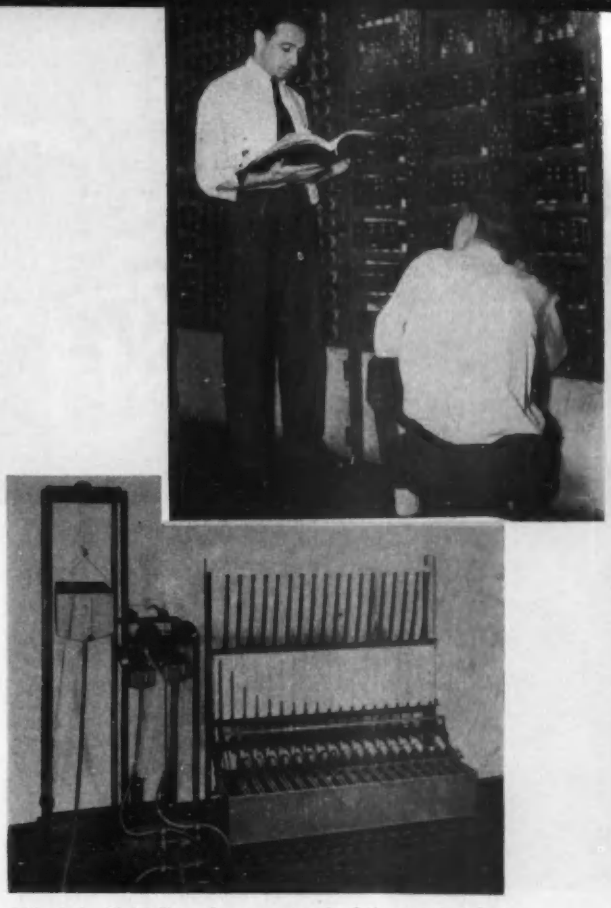


FIG. 4. A—Hydraulic analog computer simulating transient heat flow in eight slices or increments. Above resistance box of calibrated flow tubes is gang switch to freeze the action, and above gang switch, the standpipes. Supply tanks at left are raised or lowered to adjust pressure. Courtesy of A. D. Moore, University of Michigan. B—Passive R-C electric computer at Columbia University used for heat flow and diffusion simulations. Courtesy of Victor Paschkis.

electrical transmission networks and diffusion and heat flow problems, can be simulated most easily by series-parallel arrangements of passive elements. Most passive network analyzers are all-electric, but passive hydraulic computers have been built, too, Figure 4. The advantages of hydraulic analogs for studying transient heat flow are detailed in Reference 4.

Pneumatic analog computers are often used in the process industries in special-purpose controllers. A good current example is the one developed by Phillips Petroleum to simulate the internal—external reflux relationship in fractionating columns.

In general, resort to simulations other than electronic is to be made only in very special circumstances. The reasons are many and specifically depend upon the physical system in which the simulation is done. Certain typical objections can be noted, however, such as: the high cost of manufacturing special-size mechanical parts; the difficulty in getting sufficiently "pure" reactive elements, especially in pneumatic and hydraulic systems; the almost certain problems with interacting adjustments, which make analysis of their effects difficult; the relatively long times required to get a simulation together; and the special power sources, like constant-speed shafts or high-pressure

FIG. 5. Computer at GM Research Labs simulates automobile suspensions, applies calculated bounce, roll, and pitch motions to real car body for driver evaluations.

pumps, or clean instrument air, that may be required.

One result of all these difficulties is that analog simulations done any way but on an electronic analog computer are almost always special-purpose designs with very good reason for being.

The electronic analog computer

The several general purpose analog computers commercially available are all electronic, of the dc operational amplifier type. Physically, each one is a collection of high-gain feedback amplifiers (from several to a few hundred in number); plus precision potentiometers, resistors, and capacitors; differential relays; precision servos and function generators; and some means for connecting all of these together in any desired circuit—usually a patch panel.

An important physical characteristic that makes the use of the electronic analog computer for simulation much faster and easier than other systems is the almost perfect isolation between the input and output circuits of high-gain amplifiers with nearly 100 percent feedback. This isolation permits any practical number of individually adjustable time constants and gains to be cascaded without interaction of any of them. It is also easy, therefore, to simulate accurately whatever interactions are actually present in the system.

Potentiometers are loaded by following networks, and this problem is avoided by measuring the output (wiper) voltage as a percentage of a precision reference voltage applied to the potentiometer only during setting. Such a procedure can obviously be used for any analog system that does not enjoy the input-output isolation of the electronic computer, but setup time will be longer and parameter changes made slower.

Gain expressions for 15 operational amplifier-RC network combinations plus transfer impedances for 21 passive RC networks were presented by Roedel (Ref. 5). This paper and many others of practical interest are included in Reference 6.

The function generator is an important accessory to analog computers and takes many forms. Without function generators, the only independent variable in electronic analog computers is time (considering scale adjustments and the like as not variable during a problem run). With function generators, any input or simulated variable can become an independent variable. There are even function generators available that will produce a variable function of two independent variables. Some analog computer function generators are described in References 7 and 8.

The actual voltage ranges used for different variables in a computer simulation can usually be held to the range of 1 to 50 volts by applying appropriate amplitude scaling factors at amplifier inputs. This avoids problems from signals getting down into amplifier noise levels as well as the need for preamplifiers.

Because the measurement problem is so simple, the indicating and recording instruments used with electronic analog computers are commonly found in most electronics laboratories. Output recordings are usually made on multiple-channel strip-chart recorders with several paper speeds, such as those made by Brush Instruments and the Sanborn Co. These recorders are generally limited to signal frequency components of 100 to 150 cps maximum and are excellent for most laboratory simulation work where time can be scaled conveniently. For real time simulations that may involve frequencies to 1,000 cps or more, optical galvanometer recorders like those made by Consolidated Electrodynamics and Minneapolis-Honeywell can fill the bill, but special wide-band operational amplifiers may also be necessary.

X-Y recorders for plotting one variable against another are available from computer manufacturers such as Electronic Associates in sizes to take up to 30-by-30-in. paper. Plotters like these generally take one to several seconds to traverse the board at maximum slewing speed and so are useful only when time can be scaled to bring signal frequencies within their range. Sanborn has a new X-Y recorder that uses two optical galvanometers and ultraviolet-sensitive paper to get a frequency response of 130 cps.

Oscilloscopes are also used to observe output signals from analog computers by using a fast enough time scale and programming the computer to repeat the test run, say 20 times per sec. George A. Philbrick particularly has advocated fast simulation of this kind.

Scale factor potentiometers are generally adjusted manually by using a built-in vacuum-tube voltmeter that can be switched to read the voltage at any amplifier output or potentiometer arm. Digital voltmeters are now being used in most computers because they are more easily read to high precisions. Some digital voltmeters also have a binary-coded output.

Manipulating the simulation

Having the simulation, it can then be tested in much the same way as would be the real system. But now it is easy to test the response of the simulated system to all kinds of inputs, including those that might endanger personnel or ruin expensive equipment in the real system. Thus, even an atomic reactor can be tested to "destruction" if desired.

The procedure usually recommended is to connect the simulation for each component of the system, test these individually for proper operation, and then con-

nect them all together to test as a system.

In setting up each component simulation, scale factors (amplifier gains) for each input and feedback signal are set manually on calibrated precision potentiometers. Initial conditions of charge on any integrator (representing, for instance, preload on a spring or the liquid level in a tank at the beginning of a problem) are also set in the same way. These scale factors and initial conditions are set to values calculated for proper operation of the simulated component with the rest of the circuit and consistent with the voltage range limitations of the computer elements used. The latter implies that some kind of educated guess must be made about the range of amplitudes to be expected of each variable, so that the maximum amplitude does not overload an amplifier and the minimum does not fall to circuit noise levels. (Similarly, the problem of selecting a time scaling factor assumes a way of determining approximate system frequencies.) These problems are discussed in more detail by Johnson (Ref. 9).

The simulated component is then tested by application of some external forcing signal. A simple step change to a new constant value will generally give the most results most quickly, since it contains components at all frequencies and immediately indicates dominant natural frequencies and the degree of damping for higher order simulations and the time constants of single order ones.

After determining one-by-one that component simulators work, these components can then be connected together and tested as a system. If some of the "components" are controllers that have never been tested with a system, and especially if multiple loops will exist in the final system, the controller outputs are best left disconnected with the controlled variables set temporarily by manual pots. Then the controllers can be connected, in sequence to determine good gain, rate, and reset settings for each (see Ref. 10).

When the entire system is set up and operating, it can be handled just like the real system; that is, simulated chemical processes can be upset by "temperature changes", simulated boilers can be "started-up", simulated airplanes can be "flown", etc.

Several techniques have been developed for reducing the work in finding the optimum values for the parameters of systems being studied on an analog computer. These optimizing methods all depend on testing new values or settings in ways that are only practical on a computer simulation; and thus, through the computer, a whole new frontier is opened to the test engineer. In general, these techniques represent attempts to make automatic the experimental testing of new values in one or more system parameters in order to maximize or minimize some other parameter chosen as the criterion of performance, like system output rate or operating cost. The criterion is often a computed value that includes other factors external to the physical system under test. Such approaches go under names like dynamic linear programming and random search methods (Ref. 11 and 12).

Simulators plus real equipment

Tying simulators to real equipment in later stages of system design naturally limits the simulator immediately to real-time operation, which can produce some problems, particularly with frequency responses of computer elements and recorders. Also certain data sources for the computer may be measurement transducers on the physical system, like strain gages or pitot tubes, that will require further transduction and impedance matching. In other cases, the computer outputs may be required to drive power servos, and special power amplifiers may be necessary. But such connections are often rewarding (see Figures 5 and 6).

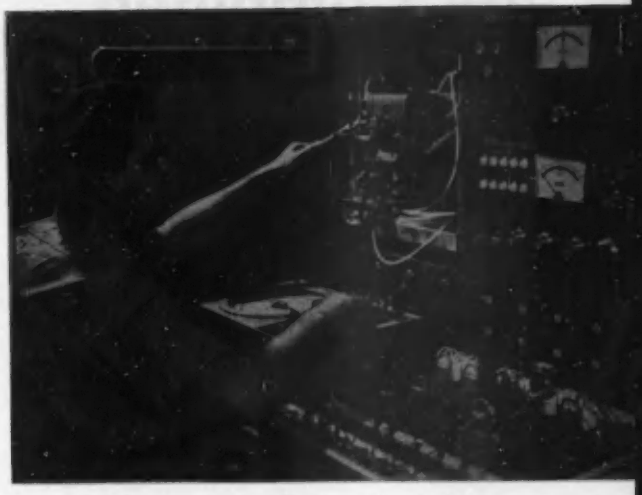


FIG. 6. Experimental setup to test pneumatic control gear with electronic analog computer simulation of process. Courtesy of Inorganic Research Laboratory, Monsanto Chemical Co.

REFERENCES

1. *COMPUTER ANALOGS FOR COMMON NONLINEARITIES*, Chester L. Dunsmore, "Control Engineering" Data File 30, (to be published, October 1959).
2. *DIRECT SIMULATION BYPASSES MATHEMATICS, SIMPLIFIES ANALYSIS*, Vernon L. Larrowe, "Control Engineering", Nov. 1954, pp. 25-29.
3. *STRUCTURAL DIAGRAMS—A SHORT-CUT TO ANALOG COMPUTER CIRCUITS*, O. Follinger and W. Seifert, "Control Engineering", July 1959, pp. 81-83.
4. *APPLICATION OF HYDRAULIC ANALOG METHOD TO ONE-DIMENSIONAL TRANSIENT HEAT FLOW*, E. L. Knuth, E. L. Kumm, "Jet Propulsion", Aug. 1956, pp. 649-655.
5. *THE ELECTRONIC DIFFERENTIAL ANALYZER*, Jerry Roedel, Case Industry Conference on Applications of Computing Machines, Case Institute, Cleveland, April 1954.
6. *A PALIMPSEST ON THE ELECTRONIC ANALOG ART*, H. M. Paynter, George A. Philbrick Researches, Boston, 1955.
7. *NEW DEVELOPMENTS IN PROGRAM CONTROLLERS*, E. J. Kompass, "Control Engineering", Sept. 1958, pp. 122-127.
8. *HOW DIODES GENERATE FUNCTIONS*, E. J. Galli, "Control Engineering", March 1959, pp. 109-113.
9. *ANALOG COMPUTER TECHNIQUES*, Clarence L. Johnson, McGraw-Hill Book Co., New York, 1956.
10. *ANALOG SIMULATION AS AN AID TO SYSTEM DESIGN*, R. G. E. Franks, Tenth Annual Symposium of the New Jersey Sect., ISA, April 1958.
11. *OPTIMIZATION BY RANDOM SEARCH ON THE ANALOG COMPUTER*, J. K. Munson and A. I. Rubin, National Simulation Conference, Oct. 1958, IRE PGEC.
12. *RANDOM OPTIMIZATION BY ANALOG TECHNIQUES*, R. Favreau and R. G. E. Franks, Second International Conference for Analog Computation, Strasbourg, France, Sept. 1958.

Testing Systems by Combined Analog & Digital Simulation

THE GIST: When a system to be simulated uses digital techniques to any great extent, and particularly where a digital control computer is used in a closed-loop, it is best tested by interconnecting analog and digital computers. Such a simulation still raises some problems, such as the computing speed required of the digital machine and the speed and dynamic range of analog-to-digital and digital-to-analog conversion equipment. Other problems are peculiar to the simulation. The relatively long set-up time, for example, makes it advisable to be able to "interrupt" the digital computer in the performance of a routine calculation and then proceed with the combined simulation. The computer laboratory at Convair Astronautics has pioneered in solving problems in combined simulations for over four years.

R. D. HORWITZ, Convair Astronautics

The original combined simulation at Convair was a test of the radio guided phase of the flight of a missile; Figure 1 gives a simplified block diagram (Ref. 1).

This simulation was performed satisfactorily using two similar approaches. The first was a simplified single-plane simulation of the missile system and used a single 10 binary digit (10-bit) analog-to-digital converter and a 10-bit digital-to-analog converter. Figure 2 is a block diagram of this approach (Ref. 2). The equipment used on this system consisted of the analog computer, two Epsco 10-bit Datrac converters, and the ERA 1103 digital computer. The combined system operated satisfactorily even though the two computers were more than 800 ft apart.

The binary digit capacity of converters is best referred to as dynamic range, for the term accuracy is misleading in combined simulations. The dynamic range of an analog signal can be described as the ratio of the maximum and minimum signal amplitudes, and is generally limited by circuit noise at the low signal levels. A very good analog system might have a dynamic range of 10,000 to 1, or 80 db. The dynamic range of a digital system, on the other hand, can be stated quite simply as the total number of binary digits (bits) used to represent a signal value, since the digital signal is accurate to the least significant bit. In general, a digital signal is capable of any desired dynamic range, and in practical applications is usually limited by the analog dynamic range.

In the first approach to solving the radio-guided missile problem, however, the analog equipment was somewhat better than the 10-bit (roughly 1,000:1) dynamic range of the converters. This limited dynamic range was considered initially and was not a handicap. The simulation was run while waiting for new equipment to allow for a 17-bit dynamic range.

The second approach to the original problem used the Epsco Addaverter system (Ref. 3) which consists of 10 analog-to-digital converters and 15 digital-to-analog converters plus control circuitry. Each converter has a conversion capability of 17 bits plus a sign bit. This problem, in which six degrees of freedom were simulated, determined the original Addaverter specifications, such as the dynamic range capability, the maximum conversion capability, and the digital word format. Several successful runs were made with the ERA 1103. But the 1103 could not be interrupted in routine calculations, so an IBM 704 with "interrupt" capability was used later for economy.

Combined simulation criteria

Based on actual experience, the decision to use combined simulation follows from several related considerations. Each computer facility has its own equipment capability and operating philosophy, so considerations important at one place may have no bearing on another. Nevertheless, the factors are:

- Economic—if a problem can be solved on either type of machine less expensively than in a combined mode, the obvious method should be used. The several solution times, machine costs per hour, and personnel hours must be compared.
- Time—besides the obvious economic comparisons above, problem solution time may be costly in many other ways. Combined simulations take more time to set up, check out, and run than the single computer method. How much more varies with the problem and the experience of the personnel, but may be stated typically as five times longer.
- Problem characteristics—this consideration may override any other if combined simulation is the only logical way to solve a problem, as for developmental

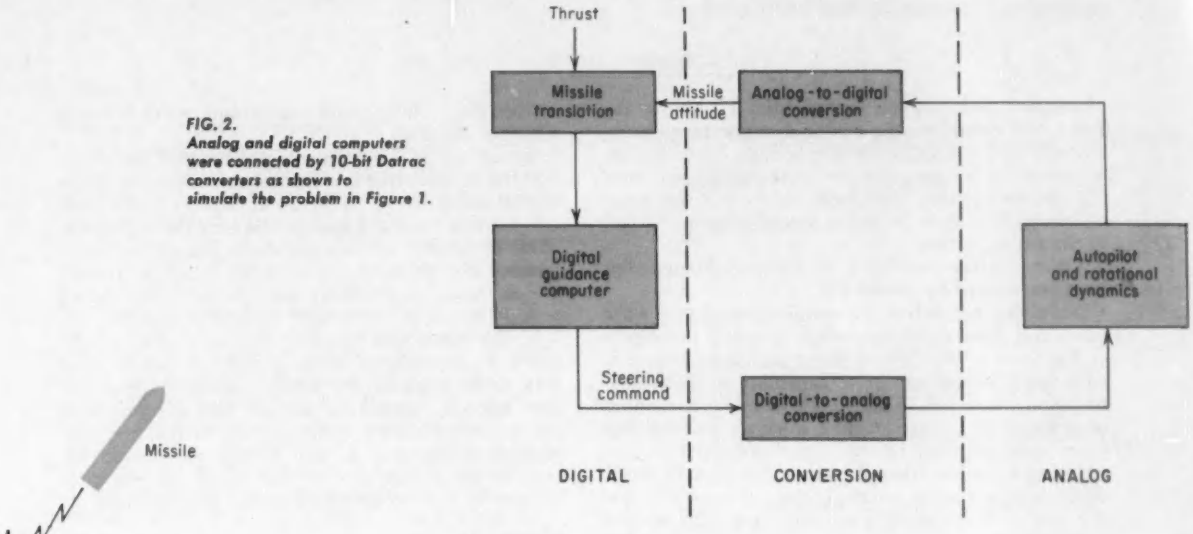


FIG. 2.
Analog and digital computers were connected by 10-bit Datrac converters as shown to simulate the problem in Figure 1.

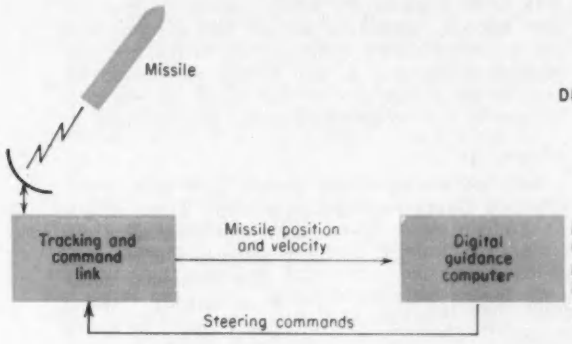


FIG. 1.
Convair's original combined simulation problem was of this radio-guided phase of a missile flight.

testing of a system that will incorporate a digital computer in its final form.

• Other factors—equipment capabilities, accuracies, and problem speed must also be considered. The numbers and capabilities of available personnel could also be a difficulty.

Having available the three modes of simulation opens what may be considered another dimension in data processing capability and allows the attack of problems that otherwise could not be considered.

The digital machine

In a general purpose data processing facility, the digital computer is not usually selected for its usefulness in combined simulation. However, there are characteristics of a digital machine that are important for combined simulation, for example:

A. Input-output characteristics, such as the capabilities of the computer in communicating with external equipment. For instance, its access time to external data is very important and will depend on its mode of operation, i.e., whether the computer is a serial or parallel machine and also whether it can read new data while it carries out a calculation. In a combined simulation it may be required to operate with peripheral equipment of other manufacturers, and buffering equipment to make pulse heights and widths compatible as well as number formats may be necessary. An important output characteristic is the maximum cable lengths that the computer can reliably drive.

B. The basic speed of operation of the machine, particularly as it affects the ability to read and write external equipment, must be considered.

C. "Interrupt" capability is valuable. Combined simulation requires considerable set-up time, mostly on the analog machine and special equipment external to the digital computer. Thus most of this set-up time does not require the digital computer to be tied in. But once things are ready to go, it is advantageous to be able to obtain the use of the computer quickly. The "interrupt" feature permits interrupting the calculation of another problem at some salient point, clearing it out of the machine to tape storage, and proceeding with the combined problem. When this feature is not available, as was the case with the ERA 1103, the simulation has to wait for time on the digital machine, which is generally the more costly.

D. Special-purpose data processing obviously requires different characteristics of the machinery than does general-purpose applications. In the special-purpose case the equipment is usually designed especially for the application. For example, if a digital control computer for a proposed system will be an incremental machine (operating by calculating only the changes in values, rather than carrying entire numerical values through all calculations), then an incremental digital computer such as a digital differential analyzer might better be used in the combined simulation.

Converter requirements

Minimum specifications for converters are as varied as the applications. Various problems that have been solved have required sampling frequencies from 2 samples per sec to as many as 4,000 samples per sec. There have been requirements of sampling times up to 10,000 per sec, as in a combined analog-digital open-loop computation of a power spectrum analysis, which could not be handled with the equipment at Convair because the maximum conversion rate that can be handled reliably by the IBM 704–Addaverter combination is 4,500 samples per sec.

The dynamic range required for various combined

simulation problems has ranged from 10 bits to the full 17-bit capability, the analog dynamic range being 100 volts/10 millivolts. On the average, 13 to 14 bits are found to be adequate for most simulations since the ambient analog noise-level blanks out the sense of bits greater than 14 unless special filtering is used in the analog system.

Other features available at Convair Astronautics have been valuable; specifically:

- The ability to control the sampling, read, and write times and rates of the converters by either the digital computer or by an external timing source; see Figure 3.
- Having a "sample and hold" capability on the analog-to-digital converters. This allows sampling a number of voltages at consistent time intervals and holding them until required by the digital computer.
- Having a flexible external grouping of digital control equipment including counters, gates, drivers, etc., for the control of the converters under various simulation requirements. An accurate time reference is desirable also. The equipment shown in Figure 3 is typical and shows the connections used for a problem to be described later. This external control equipment is mostly Convair designed.
- Having a digital computer simulator that can duplicate the input-output and control characteristics of the digital computer, as in Figure 4. Such a device saves considerable time and money, allowing the digital machine to perform its standard duties during the maintenance and checkout phase of the converter system, and especially as a dummy load for converters during set-up time if an "interrupt" feature is available.

If the conversion speed of the converters is adequate, a commutator allows added conversion channels to be available for slowly varying information. For example, maximum aircraft attitude responses amount to only a few cycles per sec, so that the sampling frequency can be low enough to include the samples for several axes on one 4,000 cps converter channel by storing converted data in the computer.

Output devices

Standard analog output devices have been generally used during combined simulations. These include oscillographic recorders and X-Y plotters. The reason is that the combined simulation is usually "analog oriented", that is, an analog philosophy involving closed-loop responses (confused by sampled-data techniques) pervades all the thinking. Also, having on-line digital read-out can slow down the digital computer to an unusable point. Digital printout is usually made during the checkout and debugging phases. During actual program runs, however, results are read on X-Y plotters and oscillographic recorders. If very close looks are required, digital data is put onto magnetic tape and printed out off-line.

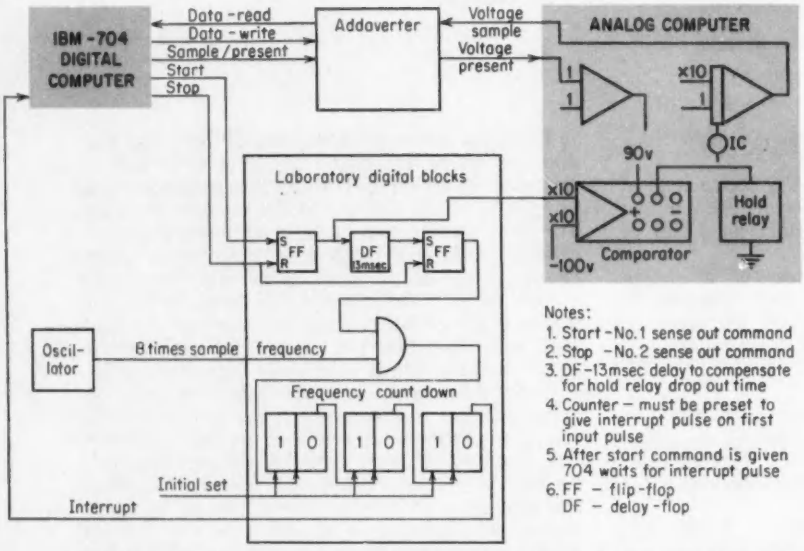


FIG. 3. Special external control equipment has been designed and built by Convair for combined simulations. Connections shown here are for fuel sloshing problem in Example 1.

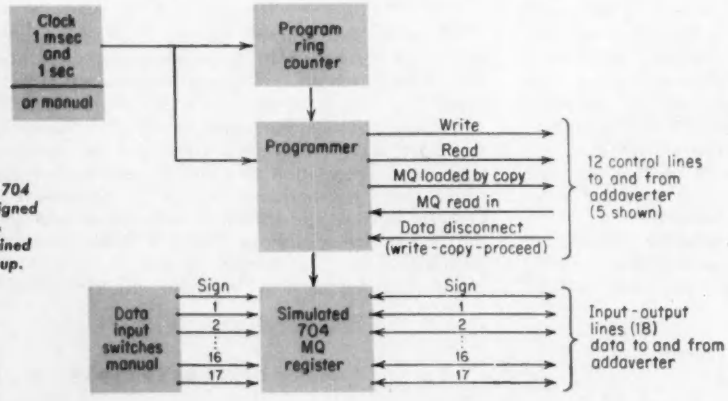

Clock 1 msec and 1 sec or manual
Program ring counter
Programmer
Write
Read
MQ loaded by copy
MQ read in
Data disconnect (write - copy - proceed)
12 control lines to and from addoverter (5 shown)
Sign
Data input switches manual
Simulated 704 MQ register
Input - output lines (18) data to and from addoverter

FIG. 4. Simulator for 704 computer designed by Convair to simplify combined simulation setup.

Actual examples of combined simulations

Two examples of the use of conversion equipment in combined simulation will be illustrated. The examples were chosen to illustrate the value of such methods as applied to system testing.

One involved varying missile dynamics due to fuel sloshing. The other was for acceptance testing of the AZUSA missile tracking system. Both problems have been solved successfully by combined simulations at Convair Astronautics.

TWO USES FOR COMBINED SIMULATION

Example 1:

The first concerns a six-degree-of-freedom simulation of a missile. Briefly, the problem was:

Provide a digital computer routine employing 10 propellant sloshing function evaluations of three independent variables: mass of liquid oxygen, mass of fuel, and total mass of the missile as produced by the analog computer. These variables are presented to the digital computer by three analog-to-digital converters. The digital computer then computes the missile longitudinal center of gravity and the pitch moment of inertia about this center of gravity. These values plus the best six of the ten evaluated sloshing functions are fed back to the analog computer through the digital-to-analog converters at five conversions per sec.

Further, the simulation requires two separate mechanizations, one for the first stage of flight to separation and the other for the second stage of flight until burnout. Figure 5 is a simplified simulation block diagram.

Sufficiently satisfactory results were obtained from the first phase of this post-flight simulation to encourage going further. To expand, more digital-to-analog conversion channels were required than are available in the present Addaverter; but fortunately, the signal frequencies involved were low enough so that conversion channels could be commutated.

Noise presented the largest single problem encountered in the simulation. During certain portions of the problem the signal levels fell into the analog noise level which consists of 60 and 120-cycle components plus the "grass" commonly found in wide-band amplifiers. Extra filtering provided some relief, but after inspecting the problem it was decided that dropping off the analog information at the noise level by ignoring the last few bits of the converter value eliminated the noise problem and would not affect the over-all performance of the simulation.

Example 2:

The second example of combined simulation involves the Addaverter in the acceptance testing of the Mark II AZUSA tracking system. The AZUSA system will be used at the Atlantic Missile Range. Briefly, it is a doppler system that provides slant range and direction cosines (l = cosine of the direction angle with respect to the X axis, m = cosine of the direction angle with respect to the Y axis) of missile trajectories. Figure 6 illustrates the AZUSA measurements.

For the acceptance testing, a Mark II AZUSA transponder was flown in an aircraft over a test course and tracked by the AZUSA system. Data were fed from the tracking station to the AZUSA phase-to-digital conversion equipment and in turn to the digital computer. The airplane, of course, does not fly at missile speeds, but its closeness provided angular rates of change sufficient to test the AZUSA equipment.

The IBM 704 in this combined system simulated the digital computer that will process AZUSA data in the ultimate installation. Data computed by the 704 feeds through the digital-to-analog converters of the Addaverter to six 11 by 17 in. and one 30 by 30 in. two-pen X-Y plotters.

Other tests of the AZUSA system have been simulated successfully using tape-recorded data as the input, instead of transponder signals from a real-time flight.

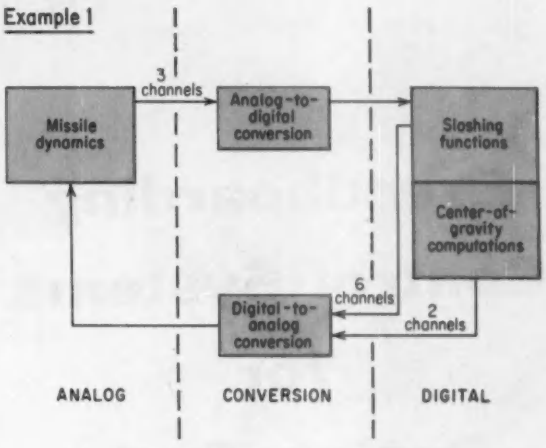


FIG. 5. Connections used for combined simulation of propellant sloshing function computation.

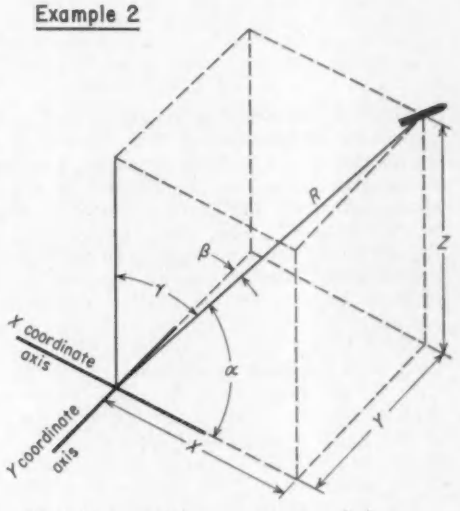


FIG. 6. Diagram of the measurements made by AZUSA missile tracking system, which was checked out by a combined simulation.

REFERENCES

1. *SIMULATE DIGITALLY, OR BY COMBINED ANALOG AND DIGITAL COMPUTING FACILITIES*, R. M. Leger and J. L. Greenstein, "Control Engineering", Sept. 1956.
2. *A TWO CHANNEL DATA LINK FOR COMBINED ANALOG-DIGITAL SIMULATION*, J. L. Greenstein, presented at the Summer General Meeting AIEE, Montreal, Canada, June 1957.
3. *SPECIFICATIONS FOR ANALOG-DIGITAL-ANALOG CONVERTING EQUIPMENT FOR SIMULATION USE*, R. M. Leger, AIEE Paper No. 56-860, June 1956.
4. *AZUSA—A PRECISION, OPERATIONAL, AUTOMATIC TRACKING SYSTEM*, Convair report AZN-004, March 1959.

Breadboarding Control Systems for Design Tests

THE GIST: The term "breadboarding" relates to the assembly of test models of systems (both analog and digital) from arrays of standardized, pre-engineered building blocks; it is cut-and-try in modern dress. Breadboarding gives the engineer more precise and reliable information about the system design in progress than any other test method—except perhaps a full-scale shakedown of the actual system itself. This precision and reliability are responsible for the continuing growth of the breadboarding field.

In breadboarding, the designer leaves the "paper stage" and comes face to face with hardware. Hence, answers to the mundane questions: "What's available?" and "Who makes it?" are the greatest assets he can have for insuring quick, efficient mechanization of his design

H. W. MERGLER, Case Institute of Technology

Although breadboarding has always been an integral step in the design sequence, it is only within the last decade that special hardware permitting true flexibility in the construction and modification of mechanical, electromechanical, and electronic system mockups has become available. Now, the engineer can proceed directly from a design on paper to an operable physical system, whose chief components may well be identical to those specified for the finalized equipment. Performance characteristics can be positively evaluated in advance. When necessary, major modification can be made with minimum expense and loss of time. Contrary to the myth spun by many overly analytic academicians, it is a rare occurrence when the product of the initial mathematical approach and the final design are identical. And in most cases, any alteration of the initial design is the result of experiment.

The four principal factors that make breadboarding necessary are:

1) Incomplete (or sometimes incorrect) information regarding the dynamic properties of components or of the load to be controlled.
2) Nonlinearities in the control system and load.
3) System noise and stray coupling.
4) Mechanical or electrical impedance mis-match.

The control engineer cannot, in most cases, deal with all of the above factors *practically* on an analytic basis; perhaps the control science may not be sufficiently advanced in some areas to allow him to do so. But he must recognize the potential difficulties and await their appearance during the experimental phases of the design.

Figure 1 illustrates the components of a general hybrid control system supplying digitally-generated command data to a digital-analog-digital loop. Assemblies such as this more than ever demand the prolific use of breadboard models.

Analog Systems

Figure 2 shows the breadboard model of an analog interpolator employed in a digital-analog control system. The assembly was constructed by mounting the required components on a drilled plate and by providing quantitative gearing interconnections. Many of the physical dimensions of similar components have been standardized so that common mounting methods can be used. The following tabulation is indicative of the breadboarding components available.

Mounting brackets

For Synchros:
Size 1, 5, 11, 15, 18, 23
Kearfott series 200 and 900
Reeves series 600 resolver
Bendix Autosyn AY-120, 130, 200, 220, 230, 240
Arma resolver–size 5
Rawson resolver–Type RL 11 C

For Servomotors:
Reeves–SM-61, 62, 401
Diehl–FPE 21, 21C, 25
Arma–03A60, 03B60, 03A400, 18A400
Kearfott–R110-2, RB-105, 106, R111-2, R112-2
Kollsman–1623B, 1361-046022 1805-0460, 2103-0411, 890, 1024, 1086, 1086B, 1186, 863, 949, 952, 972, 973, 974, 975, 976, 979, 1087, 951, 999, 1104
Servomechanism, Inc.–Type 17 series
Transicoil–1400, 1800, 2200, 2600, 3000, 2100
Bodine–KC-22, KC1-23

For Clutches:
Beckman BP-543, 583
Reeves magnetic

For Potentiometers:
Helipot-series A, B, C, D, E, F, G, J, L, T, AN, CN, AJ, JS, JSP, 5602, 5603
Fairchild–736, 746, 747
T.I.C.–RV $\frac{5}{8}$ in.
Gibbs–micropot

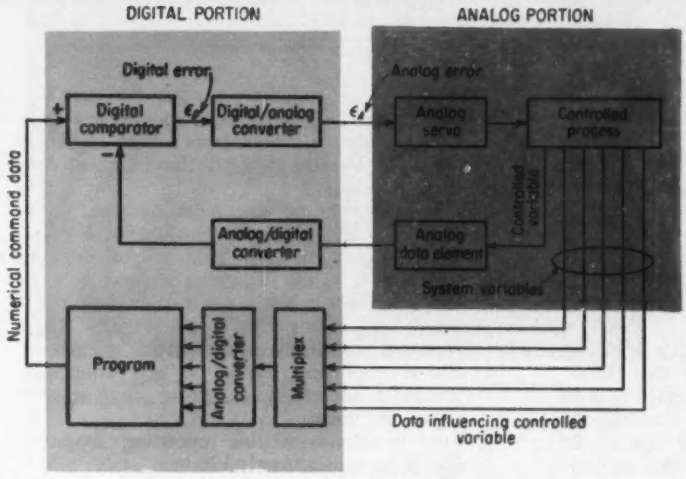


FIG. 1. Generalized block diagram of digital-analog servo system.

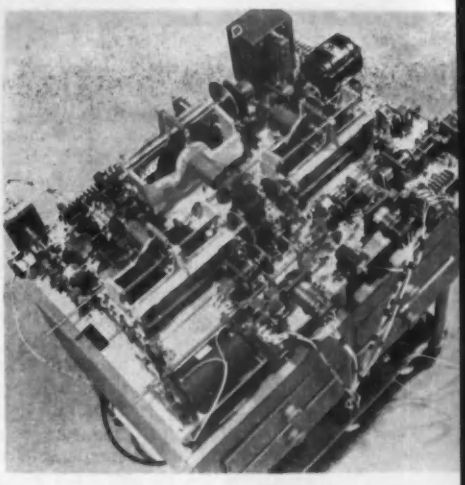


FIG. 2. Experimental breadboard of an analog interpolator for machine-tool control system.

Shaft hangers

Single or double bearings for 1/8-, 3/16-, 1/4-in. shafting

Foundation boards or grid plates

8 × 8, 8 × 16, 16 × $\frac{3}{8}$-in. with $\frac{5}{16}$-in. holes on $\frac{1}{2}$-in. centers; 14½ × 17½ × 2-in. (web) with ¼-in. slots on ½-in. centers; ditto, with ¼-28 tapped holes on ¾-in. centers; 23½ × 14½ × $\frac{5}{8}$-in. with ¼-in. slots on ½-in. centers; 17¼ × 15 × $\frac{5}{16}$-in. with same slots.

Gearing

Spur, 32, 48, 64, 72, and 96 pitch AGMA Precision Class 2; ¼ or $\frac{5}{16}$-in. bore; tooth numbers in multiples of 8 or 10; from $\frac{5}{16}$ to 4-in. pitch diameter; in stainless steel or aluminum alloy. Face widths $\frac{1}{8}$ or $\frac{5}{16}$ in. Split hubs for split clamps, or split and threaded hub with clamping cone and lock nut.

Geared head for Diehl, Kollsman, Transicoil, and Kearfott servomotors. Heads bored for standard center-to-center distances for 1, 2, 3, or 4 mesh reductions made up from standard tooth numbers.

Miscellaneous

Adjustable plate-cam assemblies, bellows couplings, Oldham couplings, dial assemblies (36, 100, 360 divisions) rotary limit stops, shaft adapters (for all standard servomotors, synchros, and resolvers), ground shafting, clamps, spacers, slip-clutch assemblies, limit-switch brackets, handwheels, spur and bevel gear differentials, ball-disc integrators (with screw, rack and pinion, or linear integrand inputs).

Principal suppliers for the above equipment include:

1) Reeves Instrument Corp., Garden City, L. I., N. Y.
2) Pic Design Corp., East Rockaway, L. I., N. Y.
3) Dynamic Gear Co., Amityville, L. I., N. Y.
4) Beckman-Helipot, Newport Beach, Calif.
5) Servomechanisms, Inc., Garden City, N. Y.
6) Servomex Controls Ltd., Crowborough Hill, Harvis Brook, Sussex, Eng.
7) Belock Instrument Corp., New York 15, N. Y.

The design philosophies of most manufacturers of mechanical breadboarding equipment are quite similar. The one principal difference is in the foundation board. The proponents of slotted boards state that their tapped hangers provide an infinite number of mounting locations. This is true only along one axis when the hanger is placed so that both mounting screws are in the same slot. The same limitations must be assigned to the drilled foundation boards which

FIG. 3. Drilled foundation board using hangers with slotted bases and captive nuts. (Mechatrol Div., Servomechanisms, Inc.)

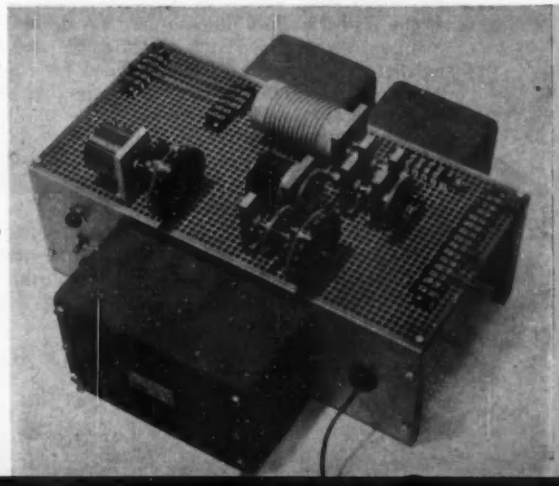


FIG. 4. Slotted foundation board employs tapped hangers. (Helipot Div., Beckman Instruments, Inc.)

use a captive nut in the T-slot base of the component hangers. The tapped board with the surface L-clamps offers the greatest range of adjustment along both axes. A limitation of this design is possible interference by clamps and other hangers when mounting closely coupled components. The assembly of Figure 2 employs this technique; the breadboard equipment shown was designed by the writer and is not commercially available. Figures 3 and 4 illustrate the other assembly methods.

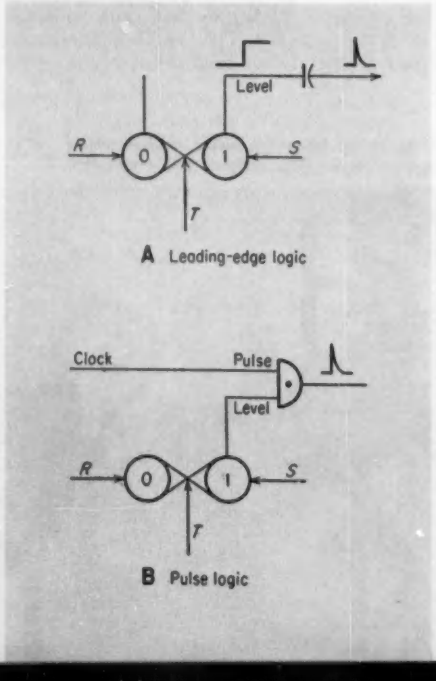
Once a satisfactory breadboard model has been constructed and demonstrated, it is essential that the designer recognize *why* its operation is satisfactory if he is to do a good job of repackaging later. Does the system hold specified temperature rise only because the open construction permits adequate motor cooling? Is it stable due to frictional loads which are only a byproduct of the breadboard construction? Is its frequency response adequate as a result of a multiple-mesh, low-inertia gear train which will not fit in the space allotted to the final design?

Digital Systems

In recent years, a number of manufacturers have introduced series of compatible logical elements especially intended for digital computer development. The requirements of logic for computation and for control are basically identical; however, the frequency requirements exclusively for computation exceed those for control by a factor of 10 or more. Therefore, the control systems engineer is often required to employ (and pay for) equipment whose performance greatly exceeds his requirements.

In recognition of the explosive growth of the application of numerical techniques to automatic controls, it seems appropriate to enumerate the gross requirements of the control engineer for compatible logic. In formulating these requirements, it was remembered that the control specialist's talents are foreign (in various degrees) to those of the engineers who do sophisticated logical design and quantitative electronic design. Ideally, then, the equipment should permit the systems designer to go directly from a logic diagram or equation to an operable circuit without any intervening electronic design.

FIG. 5. Diagrams show distinction between leading-edge and pulse forms of logic.



For control applications, compatible logic should meet the following general requirements:

1) The designer should be able to synthesize any conceivable logical expression without excessive multiplication of units; yet, the number of different logical elements should be kept to a minimum to preserve the general-purpose philosophy.
2) Signal amplitudes should be large enough to provide a comfortable margin of safety between signal and noise.
3) The minimum reliable operating frequency should be approximately 100 kc.
4) The system should employ leading-edge logic to avoid the burden and expense of excessive nonlogical gating. Figure 5 illustrates the basic difference between leading-edge and pulse logic.
5) All logic should be fully compatible, with input and output impedances chosen to permit the designer complete freedom in interconnecting the elements.
6) The logical components should be available in two forms: 1) highly flexible building-blocks for development and 2) identical circuitry, packaged for convenient integration into a final system design.
7) The development building-blocks should have understandable mnemonic symbols on their patch panel to conform with an accepted set of logical symbols.
8) The development building blocks should be packaged to accommodate patch panels large enough for convenient patch-cord manipulation.
9) The cost of individual logical elements should be low enough to transfer them from the category of "instrumentation" to that of "hardware".

The utilization of compatible digital logic for numerical control system development achieves the following results:

1) The designer is free to explore a number of possible solutions without loss of time or the incurrence of excessive construction costs.
2) The correctness of analysis and logical design can be immediately evaluated.
3) Parameters such as delay times, rise times, signal-to-noise ratio, and signal degeneration can be studied and operating ranges defined.
4) Variations in circuit performance due to manufacturing tolerances of dynamic elements, power supply variations, temperature changes, etc., can be determined
5) If the logical building blocks used for development are applicable to final construction, or if a parallel set of identical logic designed for construction purposes is available, the burden of correct interpretation of many of the results gained from the breadboard is diminished.

The following is a tabulation of some commercial equipment adaptable to the breadboard development portion of automatic control systems.

Burroughs Corp., Electron Tube Division. This series of compatible digital vacuum-tube circuitry employs pulse logic and is intended for combination into laboratory instrumentation. All units are designed for

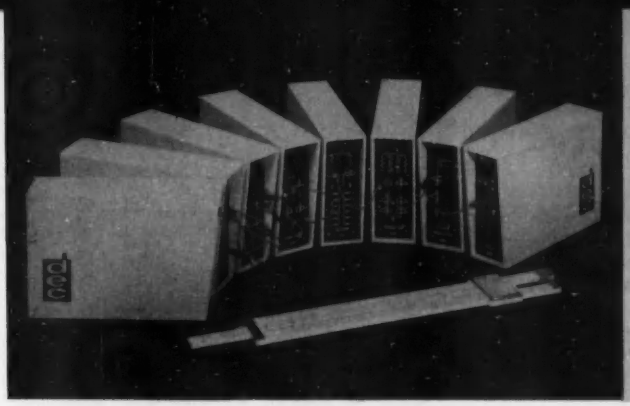


FIG. 6. Compatible logic building blocks supplied by Digital Equipment Corp.

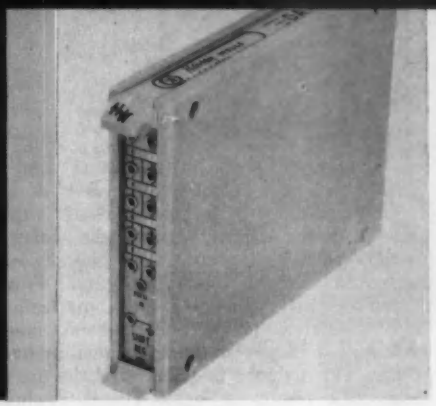


FIG. 7. Four-stage shift register is one item in line of digital breadboard components manufactured by Harvey-Wells.

19-in. rack mounting and are interconnected by coaxial cable with BNC connectors. The standard information pulse is 0.1 microsec; standard dc levels are 0 and 23 volts; and the elements are essentially 2.5-mc circuits. The series includes the following units:

No. 1003—Triple pushbutton pulse generators producing three separate (random or synchronized) 0.1-microsec pulses.
No. 1006—Wide-frequency-range pulse generator producing a standard pulse by pushbutton or in the free running mode from 15 cps to 4.5 mc.
No. 1020—Pulse standardizer, which produces a 0.1-microsec pulse from a variety of input waveforms and levels.
No. 1105—Flip-flop featuring RST circuit with standard level output.
No. 1201—Coincidence detector, which senses coincidence between a dc level and a 0.1-microsec pulse.
No. 1202—Diode coincidence detector, which senses coincidence of two to five dc levels.
No. 1301—Pulse delay; a multivibrator analog delay adjustable over the range from 1.0 to 80,000 microsec.
No. 1302—Pulse delay; a tapped delay line for delays from 0.1 to 1.9 microsec in 0.05-microsec steps.
No. 1501—Pulse gater, which gates pulses for a variable period from 0.3 to 6,000 microsec.
No. 1601-2—Mixer, which mixes four or five standard positive pulses with 1-db attenuation.
No. 1603—Mixer, which mixes four standard levels and produces a standard level.
No. 1901—Inverter, for inverting the standard levels.

This equipment is extremely flexible, but quite expensive both in unit cost and power supply requirements. Since there is no companion logic which can be used as equipment construction hardware, the units must be used only as logical design tools or test instrumentation. The high frequency capability of the series cannot be fully exploited in the control field and, the pulse logic which is employed here for maximum reliability at these frequencies is a limiting factor in many potential control applications.

Digital Equipment Corp. This series of compatible digital transistorized circuitry employs pulse logic. The units are constructed in two package forms designated by the manufacturer as "Digital Test Equipment", Figure 6, and "System Building Blocks". The circuits of comparable elements in each package form are logically identical; their difference rests in the fact that the test equipment line is designed as a laboratory design tool and has all of its terminals for interconnection brought to a diagrammed front panel. The building block packages, in contrast, have no front panels and simply plug into a multiple-connector socket, from which the interconnecting wiring between units is permanently installed. Such a parallel line of development logic and construction logic permits the successfully operating digital breadboard to be exactly reproduced in the final design. The DEC building blocks are moderately expensive, compact units which are interconnected by means of ordinary No. 22 stranded wire and stacking banana jacks. Nine elements can be mounted in a panel which fits a standard 19-in. rack. A single power supply can accommodate a typical assortment of 45 units. The standard information pulse is −2.5 volts of 70 millimicrosec width. The standard dc levels are 0 and −3 volts. Logical operations are performed by combinations of saturable transistor inverters. The series includes:

No. 103—Inverter; six-transistor inverters for use as pulse gates and level gates.
No. 110—Diode; two six-input negative OR circuits with output amplifiers.
No. 201—Flip-flop; five-megacycle RST circuit with output amplifiers, indicator, and two general-purpose inverters. A carry pulse is generated for counting.
No. 301—Delay; pulse delay from 0.25 to 500 microsec with a negative level during the delay and a standard pulse at the end of the delay.
No. 401—Clock; variable frequency (500 cps to 5 mc) oscillator with pulse output. Lower frequencies available by using an external capacitor.
No. 601—Pulse amplifier; amplifies and standardizes pulses in width and amplitude.
No. 410—Pulse generator; generates standard pulses from pushbutton switch.
No. 650—Tube pulser; provides pulses compatible with vacuum-tube circuits.
No. 666—Level amplifier—Provides compatible signal levels between the standard signal levels and those of other digital circuits.

This equipment meets many of the requirements for digital control breadboarding circuitry previously defined. Its performance, however, greatly exceeds the requirements of such equipment when employed in control systems.

Harvey-Wells Electronics, Inc. This logic is for practical purposes identical to that of the Digital Equipment Corp., since both organizations drew on the research and development experience of the Lincoln Laboratory TX-2 computer for their basic design. The HW units have slightly different signal magnitudes and their packaging is somewhat more compact. This manufacturer produces parallel series of units for system development and system construction, designated as "Data-Blocs" (Figure 7) and "Data-Pacs" respectively.

Computer Control Corp. This series of compatible digital circuitry is designed for *leading-edge* logic. Such logic employs a differentiated dc level charge as

the data signal, Figure 5, instead of using this level charge to gate a standard pulse as is done in pulse logic. The series is transistorized and is designed on plug-in cards. Wiring between the socket terminals of elements is permanent, which imposes certain flexibility limitations in development work. Finalized construction can be done with the same facility as with HW and DEC units. The frequence range (up to 100 kc) is ideally suited to control system applications. This reduced frequency and the use of leading edge logic results in logical elements whose cost is approximately one-third that of comparable high-frequency pulse logic. The CCC series comprises:

No. FF 103—Flip-flop; an RST circuit with provision for ac- and dc-coupled set and reset inputs and an ac-coupled complementing input. State is indicated by neon lamp.

No. PA 104—Pulse amplifier; provides pulse amplification and standardization (13 volts minimum at 2.5 microsec).

No. DG—Series of diodes current gates of one, two, or three circuits with from two to 10 inputs.

No. EF 101—Emitter follower; impedance-matching driver between flip-flop outputs and diode gates.

No. IA 103—Inverter amplifier; provides signal inversion of the output signal with respect to the input.

No. MV 103—One-shot multivibrator; provides an analog delay of a pulse edge from 10 microsec to 0.25 sec.

No. OB 103—Blocking oscillator; a frec-running oscillator whose frequency covers the range from 10 cps to 100 kc. Manual and delayed output pulses are available.

Engineered Electronics Company. The EECO compatible logic series is designated as the "Computer Series". This is leading-edge, vacuum-tube, card plug-in circuitry designed for the frequency range to 150 kc. All wiring is done at the socket behind the panel and therefore the equipment is not quite adaptable to development tasks as it is to final design construction. The units are compact, relatively low cost, and are quite ideally suited to digital control applications. The series consists of the following units:

No. Y-100, 101, 102—Flip-flop; RST circuits with frequency limits of 150 kc, 1 mc, and 150 kc. Set and reset inputs are provided with ac and dc coupling as well as ac coupling to the complementing input. Y-102 provides for both delayed and undelayed outputs.

No. Y 103—Shift Register Element; a clamped flip-flop with delayed outputs uses a shift register control element.

No. Y 104—One Shot; a monostable multivibrator that provides an analog control of the delay of a pulse edge over the range from 30 to 70 ms.

No. Y 105, 6—Cathode Follower; impedance-matching circuitry for coupling high-impedance signal sources to loads without signal degeneration.

No. Y 108—One-Digit Adder; circuitry performs the logical task of adding two binary numbers plus a carry and producing a sum and carry output digit.

No. Y 109—One-Digit Subtractor; circuitry accepts serial binary digits for subtrahend, minuend, and borrow, and generates a difference digit and borrow output.

AVCO Manufacturing Co. This series of compatible digital transistor circuitry employs leading edge logic and uses plug-in card-type construction. The elements measure only 2½ x 2 x ½ in.; 25 elements can conveniently be located across a standard 19-in. rack. Input/output connections from each socket are brought out on taper pin connectors at the rear, allowing a good measure of freedom in interconnecting the elements. Such connection does impose a slight restriction on flexibility when using the equipment for development purposes. The maximum reliable operating frequency of the logic exceeds one megacycle. This equipment is ideally suited to numerical control-circuitry construction from the standpoint of frequency range, leading-edge logic, size and price.

No. BT1—Flip-Flop; basic RS circuit operates from either pulse on level inputs with rise times of 25 volts/microsec. It may be externally connected to form a T element.

No. ME1—One Shot; monostable element provides a nominal 0.5 microsec analog delay of a pulse edge relative to the input trigger.

No. AG1—AND Gate; diode element containing two three-input AND gates and two two-input AND gates.

No. ORI—OR Gate; contains two five-input OR gates with emitter-follower output stages.

No. GAl—Gated Amplifier; provides amplification, pulse standardization, and retiming for signals derived from passive logic.

It is extremely important to point out here that in all of these systems of logic, the philosophy of "almost indiscriminate compatability" dictated the design. There are a number of manufacturers (see Table) of digital logic and pulse circuitry which can be very effectively used in the construction of numerical control circuitry, but certain burdens are left to the engineer regarding impedance matching, signal levels, polarity, etc., between the units.

SOME MANUFACTURERS OF DIGITAL PLUG-IN CIRCUITRY

MANUFACTURER	DYNAMIC ELEMENT			PRODUCT
	TUBE	TRANS.	MAG.	
Engineered Electronics Co. 506 East First St. Santa Ana, Calif.	√	√		Flip- flops, blocking oscillators, one-shots, phantastrons, level gates, pulse amplifiers, linear amplifiers, cathode followers, emitter followers, multivibrators, sine-wave oscillators, reset generators, power-supply regulators, pulse inverters, ring counters, pulse gates.
Walkirt Co. 141 West Hazel St. Inglewood 3 ,Calif.	√	√		Flip-flops, scale-of-three counters, one-shots, triggers, pulse generators, crystal oscillators, twin-T oscillator, differentiating amplifier, square-wave generator, gated oscillator, blocking oscillator, amplifier-cathode follower, power amplifier, voltage amplifier, differential amplifier, gate, phantastron emitter follower.
Dayton Electric Products Co. 320 Vermont Ave. Dayton 4, Ohio	√	√		A stable multivibrator, flip-flops, blocking oscillator, cathode followers, gates, one-shots, Miller sweep generator, Pierce crystal oscillator, phantastron, Schmitt trigger, AND gate, OR gate.
Epsco 588 Commonwealth Ave. Boston, Mass.		√		Flip-flops, diode AND gates, diode OR gates, inverting amplifiers, noninverting amplifiers, cathode followers, one-shots, blocking oscillators, level converters, signal generators, decade counters.
DI/An Controls, Inc. 40 Leon St. Boston 15, Mass.			√	Core-transistor or core-diode logic elements that can perform all of the logical functions and connectives.
Airtronics, Inc., Datakor Div. 522 Dorsey Lane Washington 16, D.C.			√	Core-diode shift registers.

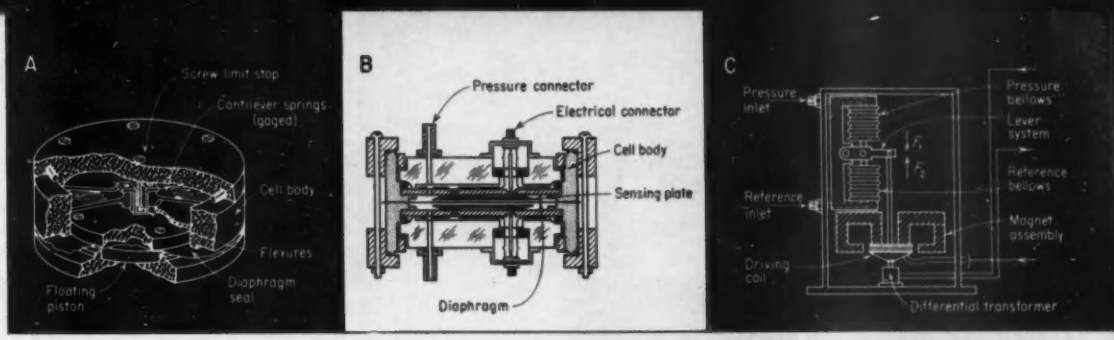


FIG. 1. Three special-purpose static pressure transducers.

Sensing the Test Variables

Today the demand for faster, more accurate test measurements is pushing conventional transducers to the limits of their performance. This article takes a quick look at a few of the problems and some of the new transducer techniques.

FRANK McPARTLAND, Control Engineering

Measurement, an indispensable part of any test activity, usually involves three distinct operations: sensing or transducing of the variable to be measured, signal conditioning and transmission, and display or control initiation. This article concerns only the first of these and reviews some of the transducer problems associated with test measurements. The more interesting aspects of transmitting and recording test data will be discussed in separate articles.

Transducers and transducer techniques for measuring the test variables logically fall into either of two broad classifications:

- those which are generally considered standard practice for operational systems and processes, but are equally well suited for test applications, and
- those which, for one reason or another, are specifically designed to meet certain test requirements.

Until quite recently, most test measurement problems were well within the capabilities of the more accurate conventional transducers; and the normal evolution of these devices kept pretty well abreast of the test engineer's demands for improved accuracy, sensitivity, reliability, etc. (Ref. 1). Following World War II, however, the sudden acceleration of research and development efforts brought with it not only an increase in the amount of test activity, but also a marked increase in the complexity of the measurement problems.

Since much has already been written on the application of conventional transducers in test work, the following pages will be devoted entirely to some of the more interesting transducer problems for which conventional equipment has proved inadequate.

Flight Testing

In the many flight test facilities operated by the military services, government agencies, universities, and private industry, instrument engineers are constantly confronted by new transducer problems. Quite often, these have no counterpart outside the field of aeronautical research. Although the variables that must be sensed are a familiar few (pressure, temperature, strain, etc.), the performance required of the transducers and the environmental conditions to which they are subjected seriously limit the application of techniques developed in other areas. A few examples will illustrate some of these peculiar requirements.

Static pressure

For years the fluid manometer has been one of the most accurate means of measuring relatively low static pressures. In wind-tunnel tests, for example, multimanometer installations are often used to study the effects of pressure distributions across airframe sections. In this and other applications, pressures are read directly from the individual tubes. However, where tests must be run at frequent intervals and a large number of pressure points are involved, manual data logging becomes an expensive, time-consuming operation. This situation has gradually led to the development of several static pressure transducers which not only lend themselves to high-speed data handling techniques, but also maintain the accuracy of the fluid manometer. Figure 1, above, illustrates three devices used at various NASA and Air Force facilities to satisfy these requirements.

In transducer A, developed at the NASA's Ames Research Center, differential pressure acts on a rigid piston which is sealed by a thin neoprene diaphragm and supported by two cantilever beams. Strain gages attached to these beams provide an electrical analog of the applied differential pressure. Cells have been made to cover differential ranges of from plus or minus 4 to plus or minus 100 psi. Total thermal, hysteresis, and nonlinearity error is less than 0.05 percent of the full range. In the Ames multiple-pressure system, outputs from 100 such cells are scanned, digitized, and recorded in about 40 sec (Ref. 2).

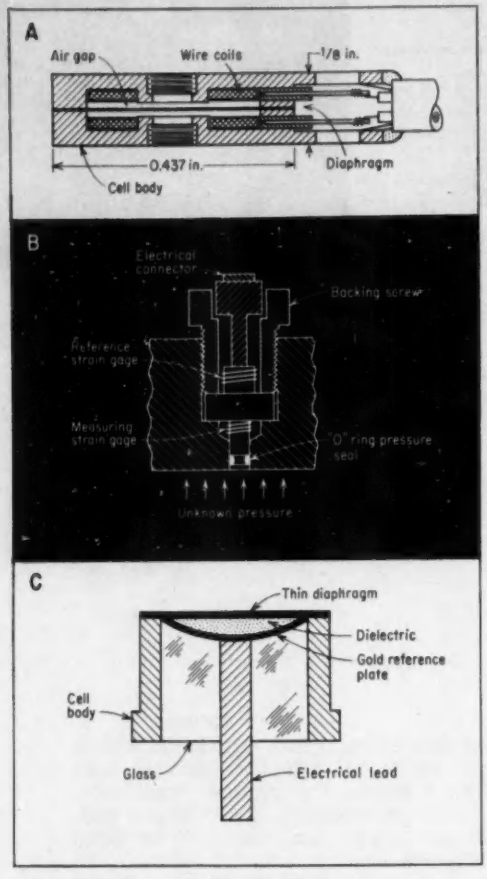


FIG. 2. Three dynamic pressure transducers.

Because of unstable forces introduced by the neoprene diaphragm, performance of this type of cell falls off below a range of plus or minus 1 psi. In low-density wind tunnel tests, for example, the variable-capacitance transducer, B, is considerably more effective. This device consists of an electrically grounded diaphragm stretched between two sensing plates to form two capacitors. External trimming capacitors provide initial balance. When a differential pressure is applied to opposite sides of the diaphragm, it produces a proportional change in the plate-to-diaphragm capacitances, which can then be fed to a suitable bridge circuit. Transducers of this type require careful shielding and have been made with ranges of from plus or minus 0.01 to plus or minus 0.4 psi.

The third example, C, although commercially available, was also designed specifically for test work. Here the unknown pressure and a constant reference pressure are applied differentially to a pair of precision bellows. Through an essentially frictionless lever system, an unbalanced bellows force, F_1, drives the core of a differential transformer. A servo amplifier, sensing the change in transformer output, supplies the driving coil with a signal from a feedback potentiometer. This develops in the driving coil a force, F_2, sufficient to balance the differential bellows force and return the lever to the null position. At the Air Force's Arnold Engineering Development Center, 250 of these transducers time share 50 servo amplifiers. Pressures are scanned at a rate of 50 points every 28 sec., with the desired 0.1 percent accuracy (Ref. 3).

Dynamic pressure

When flight testing requires data on the dynamic fluctuation of pressures, transducers with good response characteristics must be used. How complex these devices become depends on the relative importance of such characteristics as stability, size, accuracy, and response. Figure 2 illustrates three special-purpose dynamic pressure transducers.

The variable air-gap inductance type, A, is particularly well suited for buffeting and flutter measurements. Its acoustical cavity, while limiting dynamic range, improves thermal stability. Whereas a flush-diaphragm strain-gage type might have a higher natural frequency, it is also subject to considerably more zero drift due to environmental temperature changes and electrical power dissipation in the gage wire.

For high-level transient pressures, such as those encountered in the compression chamber of a gun tunnel or a free-flight model launching tube, transducers must be capable of peak pressures up to 150,000 psi at frequencies as high as 50 kc. One type designed to provide this kind of performance is the Ames piston-type transducer, B. In this device, the unknown pressure exerts an axial force on the piston. This sets up a proportional circumferential strain which is immediately sensed by the lower strain gage. The upper strain gage simply provides compensation.

A third kind of dynamic pressure transducer, the dielectric compression type, C, is capable of responding to pressure frequencies of 200 kc or higher. In operation, the unknown pressure acts on a flush diaphragm to compress a thin layer of dielectric material. Change in capacitance between conducting films on either side of this dielectric material provides a measure of the applied pressure. A typical application requiring the high frequency performance of this type of transducer would be the study of gas dynamics in shock tubes (Ref. 2).

Strain gage balances

The development of these and other special purpose pressure transducers has challenged the imagination of the flight test instrument engineer. But equally challenging have been the problems associated with the development of precision strain gage balances for

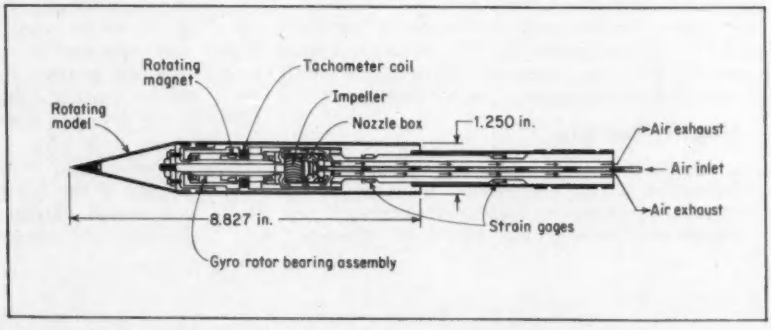


FIG. 3. High-speed air turbine and strain-gage balance for sensing Magnus moments.

measuring the static and dynamic forces and moments encountered in wind tunnel tests. In this area, however, effort has been concentrated on the overall balance design rather than on the development of new strain-gage types.

The design of model strain gage balances in current use are as diverse as the programs for which they were developed. No simple classification is possible. They vary with regard to: forces or moments being measured, accuracy and range requirements of the gages used, environmental conditions under which they must operate, etc.

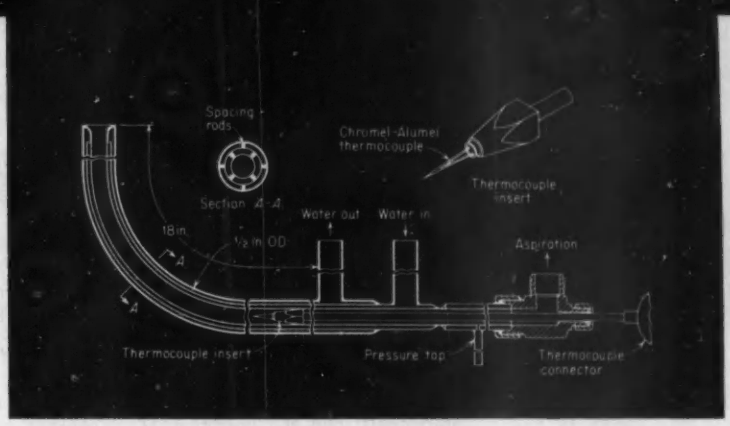


FIG. 4. Cooled-gas pyrometer probe for high-temperature studies.

The following example illustrates some of the peculiar problems involved in developing a single special-purpose balance for use in a supersonic wind tunnel at the Naval Ordnance Laboratory (Ref. 4).

It had been known that certain aerodynamic forces, called Magnus forces, affected the trajectories of conventional rotating missiles flying in a cross wind. To study this effect more closely in a 16 by 16-in. supersonic tunnel, it was necessary to construct a model of a typical missile, provide some means for rotating it, and design a balance to measure the Magnus moment. Simulation of full-scale conditions required rotational speeds in the model considerably higher than those of the prototype. This led to the design of a miniature air turbine, made to fit inside the model. The model was then mounted on the end of a four-component strain gage balance, as shown in Figure 3. A precision bearing assembly permits rotational speeds as high as 120,000 rpm. A simple tachometer built into the turbine generates a sine-wave output with a frequency equal to the speed of the rotating model. The strain gage balance was designed for pitching loads up to 50 lbs and Magnus moments on the order of 1/20 of the pitching moments. Actual measurement is performed in about 30 sec by accelerating the model through spin rates up to 80,000 rpm at discrete angles of attack.

Engine Testing

In engine testing, as in flight testing, the most acute transducer problems are those associated with various defense projects, e.g., the design, development, and testing of propulsion systems for aircraft and missiles. Of particular interest are those problems peculiar to the performance testing of rocket engines.

In this area, main factors limiting the use of conventional hardware and techniques are the severe environmental conditions encountered and the accuracies required.

The four most frequently measured variables—those which provide the most useful data on rocket performance—are temperature, pressure, flow, and thrust.

Temperature

Accurate static and dynamic temperature measurements in solids and liquids generally can be made with conventional immersion instruments such as thermocouples and resistance elements, provided their performance is not seriously affected by conditions at the point of measurement. Far more critical, however, is the problem of obtaining accurate measurements of the extremely high gas temperatures developed in the combustion chamber. No single technique for sensing these temperatures has been generally accepted. Optical methods, although not absolutely valid, offer two practical advantages: they are capable of wide dynamic range and require no physical equipment in the region under investigation. Uncooled immersion instruments, using one or more of the so-called refractory metals, might provide a solution in the future. These materials have melting points as high as 5,730 deg F, but as yet too little is known about their thermoelectric or resistance characteristics at these extreme temperatures (Ref. 5).

One of several probe-type instruments recently developed for use in high temperature gas streams is shown in Figure 4. Called a cooled-gas pyrometer, it permits controlled cooling of a continuously aspirated sample of the hot gas. The sample is drawn through a curved water-cooled tube, after which its temperature is sensed by a thermocouple. Free stream total temperature is obtained by a relation involving internal heat transfer in the tube, gas properties, and certain readily measured temperatures and pressures (Ref. 6). In another water-cooled probe, the hot gas sample passes through two orifices before coming in contact with the thermocouple. The higher temperature is then calculated by the isentropic flow equation.

Pressure

In rocket engine testing, the number of pressure measurements exceeds that of any other variable. From propellant tanks to exhaust nozzle, a variety of static and dynamic pressures must be accurately sensed. Many of the transducers currently used for detecting these pressures were developed in other areas such as internal combustion engine research and aeronautical flight test programs. For dynamic pressure measurements, particularly in the high-temperature environment of the thrust chamber, hot gas duct or turbine transducers must exhibit exceptionally good frequency response, thermal stability, and calibration stability.

Often the performance requirements are conflicting; for example, a transducer designed to measure relatively small, high-frequency pressure changes must at the same time be insensitive to mechanical vibrations of the same frequency. A proposed solution to this particular problem requires the use of a small acceler-

ometer mounted within the body of the pressure pickup. Since the accelerometer output is solely a function of the mechanical vibration, it could be used as a feedback signal to reduce the vibration factor in the pressure signal.

Flow

Accurate flow measurements in rocket engine studies provide information on the interaction between feed lines and the combustion chamber, ignition characteristics of different propellant mixtures, hydraulic behavior of engine components, and the operation of automatic flow control systems. Many of the conventional transducers have been used quite successfully for sensing steady-state flows, but to date no one flowmeter has been developed which will satisfy all of the more difficult requirements of dynamic flow measurement. Klein, Wood, and Morgan (Ref. 7) point out that, in addition to satisfying the flow range requirement, the ideal dynamic flowmeter should 1) be able to operate in temperatures up to 1,000 deg F, 2) have a frequency response of up to 5,000 cps, 3) be accurate to within 1 percent at any flowrate or frequency, 4) be independent of fluid densities and pressures, and 5) be capable of handling highly corrosive fluids.

In recent studies, a few devices have shown some promise. One of these is the Coriolis mass flowmeter developed by Y. T. Li, in which the force produced by the Coriolis acceleration is taken as a measure of true mass flow. Figure 5 shows a sectional view of this device. Unfortunately, low frequency response and the need for high-speed shaft seals and slip ring signal commutation limits its application in rocket engine testing. A more recent development described by Li consists of a multiple-orifice drag disc attached to a force transducing system. While this technique appears to hold some promise for pulsating flow measurements, its limitations have not been thoroughly investigated.

Another transient flowmeter, developed by Lin and Berwin at Rocketdyne, features a frequency range of 2 kc, and is very sensitive to low flow rates. It uses a constant resistance electronic circuit to control a small thermistor sensing element placed in the fluid stream. Its accuracy, however, leaves much to be desired.

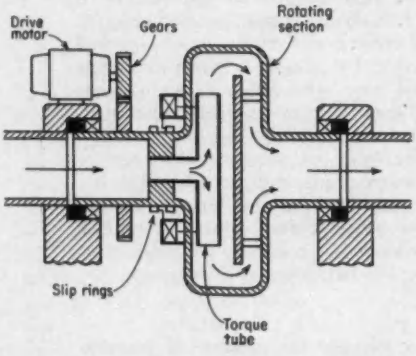


FIG. 5. Cross section of Li's true-mass flowmeter.

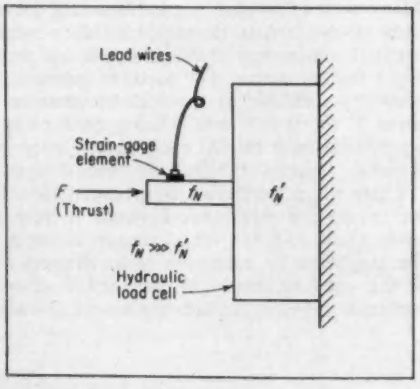


FIG. 6. Coupled system for dynamic thrust measurements.

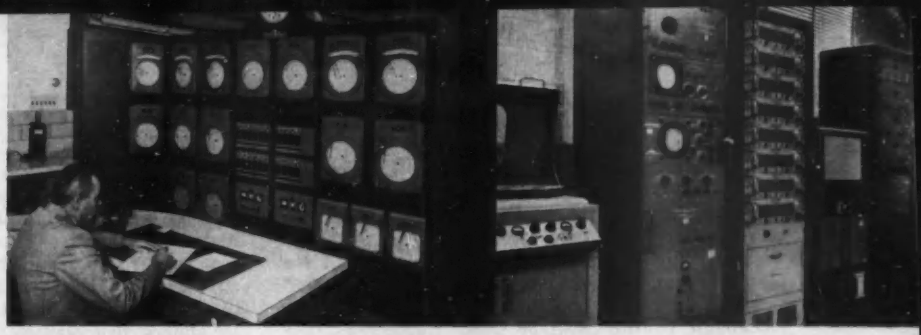
Thrust

Probably the most important single operation characteristic of a rocket engine, and the most difficult to measure accurately, is its thrust. Of primary interest today are the vibrating components of thrust, so that here, too, the most serious transducer problems involve dynamic measurement. Designing test stands for thrust measurements is very much like designing model balances for wind tunnel studies; the strain gages and load cells that will provide the electrical analogs are available, but the design of a suitable supporting structure and the proper placement of gages and cells are problems peculiar to the field.

The composite system of thrust measurement, shown in Figure 6, represents one of the more interesting approaches to the test stand design problem. Used at the Forrestal Laboratories, Princeton University, and several other research facilities, it provides a measure of both steady-state thrust and a pseudo-transient thrust component, from which the actual transient thrust can be inferred. In this system, an Emory hydraulic load cell serves two purposes: it damps the rapid thrust changes, thereby protecting the mounting structure, and furnishes an output proportional to the steady-state load. Between this cell and the thrust chamber, strain gages are installed to sense the pseudo-transient thrust value.

REFERENCES

1. *TRANSDUCERS—A COMPILATION PRIMARILY USEFUL IN OSCILLOGRAPHY.* Second Edition, Published by Allen B. DuMont Laboratories, Inc., 1953.
2. *A SURVEY OF NEW DEVELOPMENTS IN PRESSURE MEASURING TECHNIQUES IN THE NACA.* John Dimeff, NATO Advisory Group for Aeronautical Research & Development, Report 166, March 1958.
3. *PROPULSION WIND TUNNEL DIGITAL PRESSURE SYSTEM.* R. W. Kaisner, NATO Advisory Group for Aeronautical Research & Development, Report 168, March 1958.
4. *SPECIAL APPLICATIONS OF STRAIN-GAGE BALANCES USED IN THE SUPERSONIC AND HYPERSONIC WIND TUNNELS AT THE U. S. NAVAL ORDNANCE LABORATORY.* J. R. Lightfoot and C. E. White, NATO Advisory Group for Aeronautical Research & Development, Report 8, February 1956.
5. *THE USE OF THERMOCOUPLES FOR MEASURING GAS TEMPERATURES IN THE RANGE OF 2500-3500 DEGREES FAHRENHEIT.* R. E. Rush, Proceeding of the Eleventh Annual Symposium, N. J. Section, ISA, April 1959.
6. *A COOLED-GAS PYROMETER FOR USE IN HIGH-TEMPERATURE GAS STREAMS.* L. N. Krause, R. C. Johnson, and G. E. Glawe, NACA Technical Note 4383, September 1958.
7. *ROCKET ENGINE INSTRUMENTATION.* Unpublished paper by M. L. Klein, J. R. Wood, and H. C. Morgan. Rocketdyne Div. of North American Aviation, Inc.



INDUSTRIAL TELEMETERING SYSTEM

MILITARY TELEMETRY STATION

Transmitting Test Information

There are many ways of moving test data from where it is measured to where it is reduced. Here is a look at the factors that influence the choice and how the various methods compare.

FRED W. HANNULA, Stromberg Time Corp.

Because of the complexity of measurement and data reduction techniques, the data transmission aspects of a test are frequently slighted. The need for the transmission system is obvious, but it is sometimes written off with a brief specification: it must be capable of transporting the required information without intolerable losses, distortions, or inaccuracies.

It is easier to write this than to accomplish it. Losses arise because both the input devices which feed the communications system and the output devices which extract the data are not ideal. In addition, there is some loss in preparing the signal for transmission, some distorting noise is picked up by the receiver, information is lost because of limited bandwidth, and imperfections in receivers distort the end product.

Undoubtedly the best approach to the data transmission problem is to consider the entire test as a system. If the input and output characteristics of transducer, transmitter, receiver, and data reduction equipment are all known—and properly matched—the test engineer can predict the major undesirable effects and correct for them in the interpretation of the data.

In selecting a system, an engineer should look at six factors, and evaluate the pros and cons of each system for each factor.

- In what form is the information desired? For example, is the output to be analog for quick look-type recorders, or digital for computer input? Will the data have to be stored in raw form and processed later?
- What types of variables are to be measured? Are they static or quasi-static, such as superheater temperature, flue gas analysis, or level of fuel tank? Are they dynamic, such as a strain gage measurement of a missile part which goes into vibration?
- How much information has to be gathered over what period of time? Can sampling techniques be used? Are data to be transmitted continuously without interruption?
- How much reliability is required and how much can be afforded? Is the test a military one which must operate for a few hours at extreme environments? Or is it an application which will operate twenty-four hours a day for weeks or months?
- How far must the data be transmitted? If the distance is in yards a direct connection may be called for. If the distance is in miles some form of radio telemetry may have to be used.
- How much can the user spend? Although economics frequently take a back seat to other factors in military applications, industrial users of data transmission almost always keep an eye on price tags.

In looking at possible means of data transmission, one way to classify the various methods is by direct connection versus telemetry.

Direct connection

Direct connection data transmission—movement of the actual transducer signal—may be pneumatic, hydraulic or electric. The big advantage of this approach is increased reliability. Pneumatic and hydraulic lines are inherently immune to influences external to the system. Electrical connections can also be made immune by such techniques as proper shielding and the use of differential amplifiers.

Direct connection can mean a very narrow bandwidth, particularly in pneumatic and hydraulic systems of data transmission. And the cost of installing the direct connection (plus amplification equipment) limits its use when distances go above 1,000 ft. However, if the need for reliability is urgent, lines may be used

for longer distances. For example, at Langley Research Center of the National Aeronautics and Space Administration, thermocouples are directly connected to a data recording room located over 2,000 ft from where the temperatures are measured. At Cape Canaveral, variables such as pressure, temperature, and voltages are sent from the launching pad to the blockhouse control room by direct connections over distances that frequently exceed 1,000 ft.

For gathering test data, the electrical transmission line is probably used more frequently than other direct connection methods. That's because an electrical data line is less expensive to install. Pneumatic and hydraulic methods are used only when the air and hydraulic facilities have to be installed anyhow. For example, if the pneumatic control system on a refining unit is to be tested on the unit, pneumatic data transmission could be used economically because an air supply and the air tubing are already in place. But for breadboards, laboratory prototypes, or other one-of-a-kind temporary test models, pneumatics and hydraulics are too much bother and are usually restrictive in cost.

From a technical standpoint there is an additional disadvantage to pneumatic and hydraulic data transmission, particularly when distances are large. Both are slower than electrical, though hydraulic signal transmission is faster than pneumatic.

The speed of response of pneumatic systems has always been considered a major limitation of pneumatic data transmission systems. Certainly the slowness practically negates the transmission of fast changing variables with dynamic characteristics. Just how bad the lag is in pneumatic transmission lines is well known. As early as 1948 (Ref. 1) quantitative data was published on pneumatic transmission lag. The data has not changed materially since that time.

Some of this disadvantage can be overcome if the user knows the characteristics of the data transmission system. A big help is the fact that electrical analogies can be applied to the pneumatic system. In Reference 2, J. E. Samson has presented in linear transfer function form the behavior of pneumatic transmission lines. He has compared the theoretical and practical frequency responses of various combinations of line lengths and loads.

Telephone lines can be used for a direct connection, but the problem of noise raises some additional difficulty. Apparently noise is not so serious a deterrent if the data is in analog form. In the transmission of digital-type data, however, the click of operating relays and lightning strokes can create pulses which resemble the data so closely they cannot be recognized as outside interferences.

To be sure of accuracy in data transmission over telephone lines some form of coding is required to check noise pulses (changing the technique from one of direct connection to telemetry). A number of systems have been developed such as Systematic Parity Check Codes developed at the Bell Telephone Laboratories by R. W. Hamming and the redundancy check developed by D. W. Hagelbarger (Reference 4) also of BTL.

Telemetry

In its dictionary definition, telemetry is merely "remote metering". But for data transmission, the term implies converting information from a form that cannot be easily transmitted to one that can; the actual transmission; and finally, the reconversion of the data from its transmittable form to one in which it can be reduced or processed. Telemetry may be accomplished by wire or by radio. When using telemetry, it is possible to transmit more than one signal on the carrier by the use of subcarrier frequencies that are applied to modulate the carrier.

The differences in telemetry systems are based primarily on the method of encoding the signal (and how the signal is applied to the subcarrier oscillator which modulates the rf carrier): Common classifications:

PAM—Pulse Amplitude Modulation—The amplitude of the input signal modulates the oscillator so that the transmitted signal is an exact duplicate of the input.

PDM—Pulse Duration (or width) Modulation—The amplitude of the signal is converted to the duration of a transmitted pulse by a device called a keyer. At the receiving station, these pulses of varying duration can be reconverted to the original analog signal.

PCM—Pulse Code Modulation—The input signal is converted to a digital code which is transmitted.

FM—Frequency Modulation—The signal is converted at the transmitter to a proportional alternating current frequency, usually produced by having the measurement, in electrical terms, vary the frequency-determining circuit of an oscillator. At the receiver the variable frequency is re-established as a proportional direct current level.

Each system has its advantages and limitations. These are so contrasting that most installations are combinations of the basic techniques. Radio telemetry systems, for example, are described by 1) how the signal is applied to the subcarrier oscillators, 2) the type of subcarrier modulation, if any is used, and 3) the carrier modulation.

One other characteristic of telemetry equipment is worth noting in its application to testing. Military and industrial systems are so different that the same theory may even be called by different names. For example, what is PCM in a military system is called *digital telemetering* in industrial uses; what is a frequency modulation type of system to the military is called *variable frequency telemetering* industrially; and the PDM approach in the military is referred to as *pulse duration telemetering* by industrial users.

There are four usual differences between military and industrial telemetry systems. First, the transmission portion of the military system frequently has to operate under severe environmental conditions. Components must withstand high temperatures, severe shock, and vibration—but for a relatively short time. Industrial systems operate in more relaxed surroundings but continuously for long periods of time.

A second difference is in the type and number of variables to be transmitted. Most military tests involve large numbers of very rapidly changing variables. Industrial applications, in most cases, are concerned with variables that change relatively slowly, such as pressures in pipe lines, levels in tanks, flow through valves, or process temperatures.

A third difference is in the method of transmission. Military applications because of their very nature (aircraft and missiles heavily predominating) trend toward radio techniques. Most industrial applications

tend to a wire link. However there is an increasing industrial interest in microwave techniques, particularly when the user already has a microwave system installed for voice communications. And the military does use wire for reliability and simplicity.

The final difference is economic. In general, military equipment—more elaborately packaged, designed to withstand environmental extremes, and frequently highly redundant–costs more than industrial ones, often an order of magnitude more.

Selection of the best telemetry system for a test depends very much on the characteristics of the specific test. But some general comments are applicable.

Pulse Amplitude Telemetering (PAM)

Probably the oldest telemetry technique is pulse amplitude modulation. It has been used for thirty years in pipe line applications and by public utilities. It is being used less frequently today because the accuracy of the signal transmission is not as good as other newer techniques. Since the amplitude of the signal is actually transmitted, any distortion or noise makes a considerable percent error in the quantity.

Pulse Duration Telemetering (PDM)

One of the simplest systems of telemetering is pulse duration (Figure 1). The input signal enters a keyer which samples it at stated intervals, compares it to a uniformly increasing reference signal, then turns out as an output a series of pulses whose lengths are proportional to the measurement at the instant that reference and measurement are identical.

PDM can be transmitted with little deterioration over long distances either by radio or commercially available channels such as teletype lines. What does occur manifests itself in distortion of the leading and trailing edges of the transmitted square wave.

Most industrial applications of PDM have been in public utilities and pipelines where the transmitted variables change slowly with respect to sampling rate. A usual sampling rate is once every 10 sec with a typical upper limit of once every five sec.

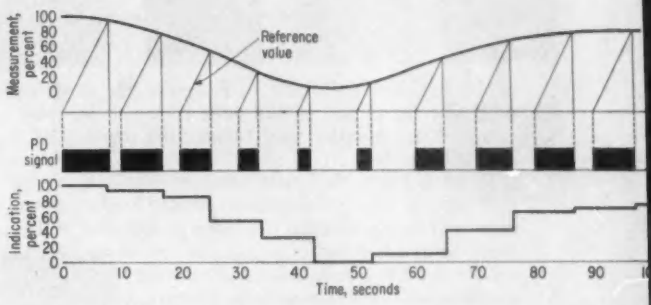


FIG. 1. Pulse Duration Telemetering.

High speed pulse duration systems have become more important. In these, by using an all-electric pulse generating technique, a sampling rate of 900 per sec is available. The cost of such equipment is much higher than the slow speed devices; its main application has been in missile and aircraft telemetry work.

Variable Frequency Telemetering (FM)

The pulse duration telemetering system described cannot follow relatively rapid changes in measurement, particularly when electromechanical keyers are used. For such applications, the variable frequency system has been developed. In this, the measurement is converted at the transmitter to a proportional alternating current frequency, usually by having the measurement vary the frequency of an oscillator. At the receiver, the variable frequency is re-established as a proportional direct current level.

The technique can be modified to make the transmission signal compatible with the on-off signal requirements of Teletype-grade channels. To do this, the variable frequency is considered as being represented by the number of pulses transmitted during a particular interval. A keying device turns out a signal consisting of standard square pulses produced at a rate proportional to the value of the measurement.

Pulse Code Telemetering (PCM)

Because noise can impair the accuracy of the signal in the PDM system, a technique was developed in

STATISTICAL TELEMETRY—A New Way to Save Bandwidth

Usually in a telemetering operation, all the data is transmitted and reduced to essential information at the receiving end. But if the data can be reduced before it is transmitted, a large saving in bandwidth is possible. One new approach is to put some of the data reducing equipment close to the transducers—as in a missile itself.

In general, the inputs to transmitting-end data reducing devices will be high-frequency response transducers such as strain gauges. Outputs are relatively slowly changing dc signals representing important mathematical or statistical information concerning the measurements. These signals are then fed into standard telemetering systems with greatly reduced frequency response (bandwidth) requirements.

Typical of such devices, which will soon be available commercially, are the following instruments:

- **a transient marker. To pinpoint in time when sianificant transients occur under vibrating conditions. When the transients can be predefined, this device can establish their time of occurrence and energy levels with about 1/1000 the bandwidth required to transmit the data for similar processing at the receiver location.**
- **a power spectrum analyzer. Since the output signal of a strain gauge measuring vibration is a composite of many frequencies, each with relatively slowly changing power levels, this device periodically scans the frequency spectrum producing a dc signal relating the distribution of power against frequency.**
- **an amplitude distribution analyzer—used particularly in studying stress characteristics. When it is important to know what the maximum stress in a member may be, and what percentage of time the stress exceeds set values, this device produces a signal relating amplitudes to the power contained in each.**
- **an airborne correlator. This device produces a signal showing the nature of the cross correlation between two measurements, for example; vibrations.**
- **a transfer function analyzer—used to define cause and effect relationships. The frequency response in terms of amplitude and phase on one variable with respect to the action of another can yield an equation defining the transfer function.**

—Arthur Westneat, Gulton Industries

which it is necessary only to recognize the existence or absence of pulses. In the pulse code system, measurements are encoded and transmitted digitally as a set of pulses.

PCM permits the most accurate transmission of data because it is less sensitive to percent kind of errors, once it is in digital form. It requires, however, much more complicated and expensive conversion equipment —both on the transmitting and receiving ends. The resultant additional complexity can cause both a maintenance and a reliability problem.

Multiplexing

The telemetry systems described have very limited use in their basic form. In such a skeleton state, they waste bandwidth, tranismitting a minimum amount of information. Because bandwidth costs money—and is tightly restricted—it has to be used wisely. The best way to do this is multiplexing.

Time division multiplexing is a sequential sampling technique, most frequently applied to PDM and PCM systems. A number of transducers are serially switched into a common keyer (or converter) so that a set of pulses is produced for each revolution of the scanning switch or commutator. A synchronizing pulse, which precedes each set, allows the receiver to assign each decoded measurement to its appropriate display.

If the variables do not change significantly during one rotation of the commutator, a number of measurements can be telemetered over a single communications circuit. In time division multiplexing, time is sacrificed for bandwidth by lengthening the time interval between samples of a particular transducer.

Frequency division multiplexing was developed for applications in which the frequency response requirements of the measurements cannot be met by a system in which data is sampled on a periodic basis. A 45 plus 20 PDM system, for example, can handle 4-5 cps data. Many signals are transmitted simultaneously, with each signal assigned a small segment of the bandwidth. A single voice grade telephone line, for example, has an available bandwidth of 3,000 cycles while a typical pulse duration system requires but a very few cycles. By frequency multiplexing, a single voice grade line can be made to simultaneously carry as many as 35 individual pulse duration signals.

Here's how it would work. Each pulse duration transmitter would operate an individual tone transmitter with a particular frequency. When frequencies from all tone transmitters are on the line simultaneously, selective filtering at the receiving end channels each signal to its proper receiver.

In comparing frequency multiplexing with time multiplexing, one important consideration is reliability. Frequency multiplexing is parallel in operation; if one subcarrier oscillator, for example, fails, only that information is lost. But because time multiplexing is a serial-type operation, all channels use certain common components. If one of these fails—such as the keyer or the converter—all data are lost.

Digital vs. analog

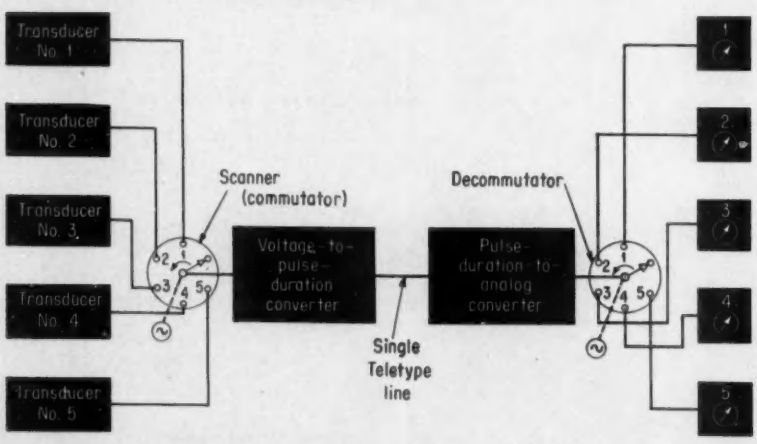
The comparative merits of analog and digital telemetering were reported at the National Telemetering Conference by L. C. Watson and M. Goldstein of Texas Instruments, Inc. (Ref. 5). Watson and Goldstein's comparison shows a technical advantage for digital techniques particularly in the comparison of relative signal powers.

Digital telemetering is particularly advantageous when the transmitted data is required in machine form for input to a computer. Conversion is easier than in the analog tranmission systems. Conversion introduces another place where accuracy can be impaired. If analog readout is required, then digital telemetry loses some of its advantage.

Frequency varying telemetering techniques are not capable of handling as large a number of variable as are PDM or PCM systems. The only limitation to the latter two is the repetition rate. If the test can tolerate an extremely long repetition rate, then a very large number of variables can be transmitted.

Practically all systems are hybrid. If a data transmission system is designed to handle only the slow-changing variables it may be inadequate. If it is upgraded to handle only the fast-changing variables, it will likely be extravagant, when an appreciable number of slowly changing measurements are involved.

FIG. 2. Time division multiplexing.



REFERENCES

1. *PNEUMATIC TRANSMISSION LAG*, M. Bradner, Technical Paper, Instrument Society of America, September 1948.
2. *DYNAMIC CHARACTERISTICS OF PNEUMATIC TRANSMISSION*, J. E. Samson, "Transactions of the Society of Instrument Technology", February 1958.
3. *THE EFFECT OF TRANSMISSION DISTANCE ON THE STABILITY OF FLOW-CONTROL PROCESSES*, D. B. Kirk, Technical Paper, Instrument Society of America, September 1950.
4. *A METHOD OF CORRECTING ERRORS IN DATA TRANSMISSION*, D. W. Hagelbarger, "Bell Laboratories Record", June 1959, pp. 213-217.
5. *COMPARATIVE MERITS OF ANALOG AND DIGITAL TELEMETERING*, L. C. Watson and M. Goldstein, Technical Paper, National Telemetering Conference, May 1959, pp. 14-24.

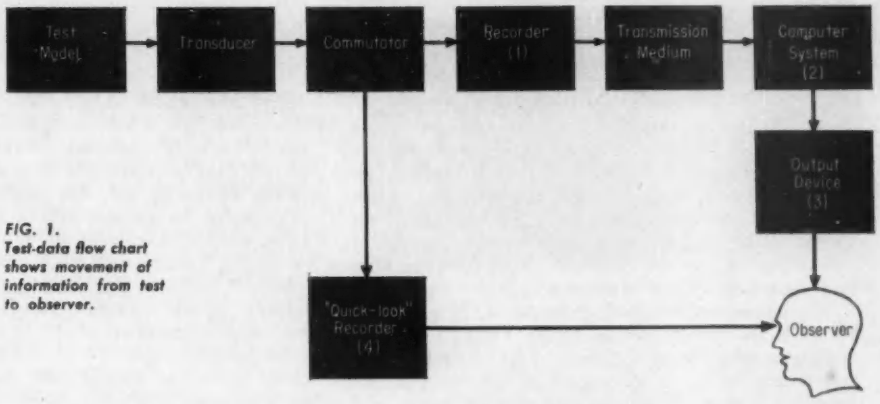


FIG. 1.
Test-data flow chart shows movement of information from test to observer.

Recording & Processing Test Data

No matter whether the design of a test is simple or complex,. it is run for one purpose only: to obtain data. Therefore, test results are precious and must be handled with care—otherwise the benefits of the test may be reduced, or lost altogether.

JOSEPH K. SLAP, Aeronutronic, A Division of Ford Motor Co.

The specialists charged with the task of recording and reducing test data may be considered to be, in essence, linguists of a very special sort. They have the responsibility for establishing the method (i.e., the language) by which the test can communicate its results for easy assimilation by the interested observer. No test can be considered successful if the final data is in a form which is difficult either to use or to comprehend. Therefore, the presentation of the data must be considered as an integral part of the test.

Figure 1 represents, in simplified form, the typical flow of information from the test model to the observer or engineer. The feedback loop, by which the observer modifies the test as a result of the observed data, has been omitted. In some systems, the transmission medium and recorder 1 appear in reverse order, or recorder 1 may be omitted entirely. The commutator is included in sampled data systems; its exact location depends on the details of the system (amplitude or frequency modulated, telemetered, etc.). For simplicity, analog-to-digital converters, sub-carrier oscillators, demodulators, and similar equipment have not been shown. These may or may not be included in a given system, depending on the conditions.

This article is primarily concerned with blocks 1 to 4 of Figure 1. The discussion of blocks 1, 3, and 4 covers data recording, while that of block 2 covers equipment and techniques for reducing the data to meaningful forms.

Data recording

Data recording devices are frequently designated summarily as analog or digital although, unfortunately, the classifiers are not always careful to state whether the designation refers to the input or the output of the recorder. Many recorders, particularly plotters, have built-in conversion circuits that accept either analog or digital inputs for a specific type of output. For example, a number of X-Y plotters handle both punched-card (digital) information and variable-resistance (analog) information and yield an ordinate-abscissa graph of discrete points. From the output viewpoint, in the sense that these are discrete points, this type of unit might be called a digital plotter; but in the sense that the plotted values must be interpolated and cannot in general be read precisely, it can also be called an analog plotter. Clearly, there are potential pitfalls in loose nomenclature.

The function of recorder 1 in Figure 1 is to preserve the raw data for later study and analysis. Photographic and magnetic tape equipment have, in recent years, acquired increased importance here, although oscillographic, punched-card, and other standard devices are still very much in evidence. The next block in the diagram, the transmission medium, can be a courier, a telemetry link, a direct wire, or a combination of these elements. Computer system 2 contains not only the computer proper, but also such peripheral equipment as data translators, curve readers, etc. Output device 3 is frequently a tabulator for data listing, but this may be replaced or supplemented by equipment such as a plotter or a card punch. The "hard copy" from this device is the end product of the data handling cycle, and is the basis for the observer's later decisions. Therefore, care should be taken in establishing the format, number of copies, scales, precision requirements, and other pertinent criteria.

"Quick-look" recorder 4 has two main advantages. First, it permits on-line observation of key data, so that changes in the test can be made during the test. This is the reason for using the quick-look recorder in an application such as a new Missile

Impact Prediction System contracted for by the Air Force. Twice per second, this system will process the latest missile tracking data and yield plots of the missile's position and predicted impact point. The range safety officer will be able to make on-the-spot decisions as a result of these plots. Should the system predict a serious deviation in trajectory, the safety officer can explode the vehicle to avoid the possibility of a dangerous off-course impact.

The second major advantage in the use of quick-look recorders also involves a time factor. Often, a crowded computer schedule or the sheer mass of data from a test prevents early processing of all information. To expedite analysis of trends, and even of some vital details, selected portions of the data are recorded in visual form. Since these data are for preliminary study, and will later be replaced by the final data, not as much care need be given to format. Approximate corrections are usually applied to the raw data for quick-look presentations of this type.

Another broad group of recorders falls under the heading "data logger"—a term applied to units of widely varying characteristics. Many data loggers are merely recorders of one type or another. But, in general, data loggers include some type of processor such as is included in the MilliSADIC systems built by Consolidated Electrodynamics Corp. Figure 2 shows a MilliSADIC installation at Pratt & Whitney Aircraft's Research and Development Center. The system consists of instrumentation for four jet-engine test cells for measuring air and fuel pressures, strain, vibration, thrust, fuel flow, rpm, shaft position, and temperatures; transducers for changing these parameters into analog voltages; and equipment for digitizing and recording on magnetic tape. A general-purpose digital computer accepts the magnetic tape. Time required to acquire, record, and compute test data from each cell is less than 60 seconds.

Normally, the flow of information in a data-logging system is from the transducer, through an analog-to-digital converter and a processor, and not via the recorder. Commutators may be placed between any two of these. The processor usually operates on selected data in accordance with programs such as: zero offset, linearization, scaling, integration, square root, and range selection. In addition, maximum and minimum values may be sensed, and off-limit outputs may be logged on special alarm recorders. The most frequently-used recorders in this application are electric typewriters, plotters, and card and tape punches.

Up to this point, the only recorders mentioned have been those which yield a permanent copy of the data. There are, however, many recorders whose output is of an evanescent nature. Included in this group are indicator lights of many types—simple units but extremely important and popular in the area of test data display. The simplest is the incandescent or neon bulb, used to show a mere on-off condition. Combinations of these with labeled locations and scribed translucent plates form the nucleus of large graphic panels that are capable of indicating more complicated situations.

Edge-lit lucite panel arrays have achieved some popularity in data display. These panels come in a number of sizes, usually approximately 2 in. square. For a decade indicator, ten of these panels are inscribed with the numbers 0 to 9 and mounted one behind the other. At the edge of each square panel is a small bulb which is lighted when its particular number is to be displayed. Normally, selection of the correct digit bulb is made by a relay matrix or rotary switch driven by the data source. Another type of illuminated decade indicator is the Burroughs Nixie tube, which can be triggered by beam switching tubes or by any suitable voltage source delivering approximately 0.25 watt. The Nixie has good frequency response; decade counters using it have operated in the megacycle region.

Mechanical indicators of many types are also available. These are rugged and long-lasting, and quite suitable where electronic speeds are not required.

A major development in nonpermanent output units has been the application of certain types of cathode ray tubes. One of these is the shaped-beam tube, which fires the electron beam through a cut-out stencil and, with suitable control circuits, yields the image of the selected character on the tube face. In this type of tube, the stencil is permanently installed so that the characters desired must be specified in advance. The Hughes Typotron and the Stromberg-Carlson Charactron are typical shaped-beam tubes. Another approach to indicating cathode ray tubes is the use of combinations of basic straight line segments to form characters. The circuits controlling the electron beam place the segments at appropriate locations and angles on the tube face, so as to form the symbols (letters, numbers, etc.). Aeronutronic, a division of Ford Motor Co., has developed a family of message entry and display equipment in which each character on the tube face is formed from a 5 x 7 dot matrix pattern. By properly controlling the beam to light appropriate dots, the desired character is written in the correct location. Figure 3 is a direct photograph of a typical message display of this kind.

The shaped-beam cathode-ray tube can also be used as the basis for character presentation of a more permanent nature. One such unit is Stromberg-Carlson's SC-5000 high speed electronic printer, which employs a xerographic printer and is capable of speeds of 5,000 lines per minute. The same principle has been applied to microfilm printers in the company's SC-4000 series.

Standard printing techniques are used when lower speeds are permissible. These include electric typewriters (10 characters per second), type-bar tabulators (150 lines per minute), and type-wheel printers (up to 2,000 lines per minute). Close manufacturing tolerances and clever engineering have permitted type-wheel printers to achieve remarkably high printing rates. (Type-cylinder printers is a better name, since high-speed units generally use a cylinder or drum, rather than a series of adjacent wheels.) However,

FIG. 2. Central data-processing room serves four jet-engine test cells. Automatic plotting of results is available to engineers in less than a minute.

the very fact of their electromechanical construction is an indication that they are reaching their upper limit in speed. A typical high-speed printer of this kind operates by striking a hammer against the paper. The hammer presses the paper and an inked ribbon against the engraved print cylinder.

In order to achieve high speeds, the paper must be fed at a continuously rapid rate, while printing proceeds "on the fly". Smudging is avoided by having the hammer in contact with the paper for an extremely short time—perhaps 50 microsec. Solving this problem is only part of the battle, however. When the hammer strikes the paper, it causes a shock wave in the paper, which tends to impress it against nearby characters, resulting in shadowing on the paper. Several of the printers on the market avoid this by staggering the characters on the print cylinder; that is, by placing a blank cut-away space on all four sides of each raised character. This, of course, requires a larger print drum for a given number of characters. Another solution has been to control the hammer throw so that the hammer moves only far enough to strike the paper, but not far enough to press into the paper and start the shock wave. In this system, the hammer return does not depend upon "bounce" from the paper; an artificial "bounce" is put into the equipment.

The severe mechanical and electronic problems (rapid regeneration of the hammer firing circuits, for example) inherent in print cylinder printers has led to such developments as the xerographic printers described above. Another newly-perfected technique involves electrographic recording. In this equipment, a shaped electrostatic charge is placed on the paper as it goes by the motionless print circuitry. The paper is then subjected, while in motion, to a bath of dry ink particles, which adhere to the charged spots. Heat and pressure are applied to "fix" the printing. Since the paper is constantly moving, its inertia is no problem; and since the printing involves no mechanical action, the high-speed limitations of the print cylinder equipment are largely avoided.

Visual records are also provided by the wide variety of available X-Y plotters, accommodating paper sizes ranging from 8½ x 11 in. to 30 x 30 in. and larger, and capable of plotting speeds up to 20 points per second, depending on distance between points. A number of these plotters place symbols and scales directly on the plots, and even interpolate linearly between adjacent points, Figure 4. A plotter manufactured by Tally Register Corp. accepts blank, fanfold paper, and prints the grid lines as plotting proceeds. Thus, paper-stretch effects are reduced.

Continuous graphs from dynamic tests are obtained by oscillographic recording. The data voltage is applied to a galvanometer whose swing controls the pen deflection. Oscillographs have been made with a hot wire in place of the pen, and a light beam has also been used. In the latter case, chemical developing is usually necessary, although several companies have recently announced units that develop the print by means of the ambient light as the paper is ejected from the recorder. This type of record may be adversely affected if left exposed for long periods in a bright area, unless it has been chemically fixed.

One of the major problems with oscillographic recording is getting the data from the chart into the computer for processing. A number of clever manual,

SDG ADR K A/C-IDN D-D_ FIX TIME_ ALT
LAX SAN N N4387A_ ____ LAX P0339 80_
TYPE SPD ROUTE-SEG ROUTE-SEG
PIP_ 140 U27_____ U21
ROUTE-SEG ROUTE-SEG ROUTE-SEG
ROUTE-SEG ROUTE-SEG ROUTE-SEG-RMKS

FIG. 3. Example of data display on face of cathode ray tube.

semi-automatic, and automatic readers have been developed, but even these fall short of today's needs when large quantities of data are required. The manual and semi-automatic units are often too slow. The automatic units have some shortcomings, including failure to follow traces properly when they either cross one another at acute angles or have points of tangency. In addition, the frequency response of oscillographs is limited. Pen units attenuate badly above 50 cps, and light-beam units above several kc.

An interesting application of oscillographic techniques has been made to satellite tracking and related problems. By a unique combination of special antennas, receivers, filters, converters and recorders, personnel at the Sohio Research Center near Cleveland are able to obtain satellite orbit data and information on high-altitude environments. The Brush Mark II oscillographs used have two channels, each of which is equipped with two pens. One pen records a time marker received from a standard Federal clock transmitter. The other records signals received from the satellite. Since two receiving antenna arrays are used, a phase-difference technique can be employed. The combined signals, when recorded, exhibit a series of peaks and valleys due to the antenna pattern. The oscillographs are also used to record the doppler shift of the satellite signal. All the above oscillations, together with the clock marks, are used to establish satellite orbit rates, directions, and precession. More elaborate plans, which include recording of the antenna calibration, are hoped to yield new angular data, as well as distance and additional velocity information.

Magnetic and film recorders

Magnetic tape recorders are free of many of the difficulties associated with oscillographs but have the disadvantage of not providing a visual trace. In addition to high frequency capabilities, tape recorders have the quality of being able to reproduce the original data signal at any time in the future. This is often invaluable, particularly in simulation programs. In addition, magnetic tape recording permits completely automatic, high-speed reduction of the recorded data. Instrumentation engineers requiring fast recording and access times can benefit greatly by advances made in magnetic recorder design as a result of its use in the digital computing field. Recording rates as high as 60,000 bits per sec track are obtainable.

In test applications, many types of magnetic tape recording are used. In direct recording systems, the data are recorded on the tape as a magnetic signal without coding or modulation. These systems demonstrate very high frequency response characteristics. In FM systems, the incoming signal is used to frequency-modulate the carrier, which is then directly

recorded on the tape. In PDM (pulse-duration modulation) systems, the recorder receives a series of square-wave pulses of different widths but constant amplitude, from a keyer. The rise and fall of each pulse is transformed, respectively, into a positive and negative "spike". These spikes are recorded on the tape at saturation levels. Other recording modes include amplitude modulation and pulse-code modulation (PCM). In the latter, the continuous signal is sampled and its value measured and converted to a binary digital code. The code is recorded in the form of saturated pulses.

Each mode of recording has its own peculiar advantages and shortcomings. For example FM has certain advantages where noise is a problem; PDM has certain advantages in multiplexed systems; and PCM, because of its digital characteristics, provides certain data reduction shortcuts. On the other hand, FM-carrier frequency response is considerably below that which is possible with direct recording at high tape speeds; PDM operates best when the signal is nearly pure direct current; and PCM generally requires a broader bandwith than does PDM. Therefore, each recording problem must be analyzed separately.

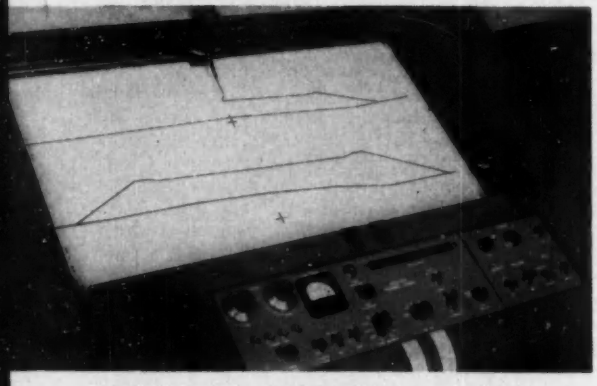


FIG. 4. Electronic Associates Dataplotter converts digital point data to accurate continuous-line presentations.

In the aircraft industry, the airframe designers enjoy saying that high speed flight has always been retarded by the failure of the "propulsion boys" to supply engines which are as advanced as the slick new vehicle designs. True or not, this claim points up the need for technical progress on several fronts whenever a complex end product is under development. In the magnetic recording field, parallel programs have been necessary to improve the design of the magnetic heads, of the tape drive mechanisms, and of the tape itself.

To emphasize the interdependence of these three items, consider one of the many objectives for improved recording, namely higher information packing density. Clearly, if more information can be recorded per unit length of tape, lower tape costs, reduced storage space, and higher processing speeds will result. To achieve this objective, the recording head must be able to apply a magnetic charge of adequate intensity to an extremely small point on a rapidly moving tape. In addition, the several recording coils within a single head, must be so aligned as to cause no electromagnetic interference between closely spaced adjacent channels. The play-back head must be built to the same exacting tolerances in order to pick up the signals faithfully. The transport mechanism must move the tape past the head without skew or jitter. Either of these faults will cause a misaligned recording which will be impossible to readback accurately.

High-density recording also requires that the tape have certain characteristics. The magnetic coating must have an extremely fine granular structure with no imperfections or flaking; the tape should have a low coefficient of friction for protection when in contact with the head (in contact-recording systems); and the tape should be dimensionally stable because stretch or shrinkage would not only affect read-back frequencies but could cause such misalignment as to result in the loss of critical data. It is a credit to the recording industry that all these problems are being solved simultaneously.

Photographic film is one of the most important test recording media now in use, particularly in the flight test region. Photographic systems, for example, establish the position of flight vehicles, essentially by a triangulation process. Care must be taken, of course, to insure complete time-identification of the film frames in such applications. Less sensational, but none-the-less important, test uses of photography are in recording of instrument panel readings (airborne, pilot plant, etc.), in studying vibration phenomena (highspeed cameras are particularly useful here), in flame analyses, in the recording of oscilloscope patterns, in photomicrographs of minute objects, and in numerous other fields. The use of photography as a scientific recording medium has been spurred tremendously in the last two decades by improvements in film sensitivity and granular characteristics, and in better understanding of infrared radiation.

Data reduction

The computer specialist has become a vital member of the testing team, with numerous responsibilities throughout a test program. He contributes to the selection of the recorders; helps establish the recording techniques, such as sampling rates, scanning sequences and modulation requirements; assists in the selection and placement of transducers, with due regard to over-all accuracy, data handling requirements, and cost; and finally, takes the major responsibility for the reduction and presentation of the data. There is no doubt that a considerable amount of manual and semi-automatic data reduction is still being done. However, the techniques involved are, by and large, fairly standard, and are well known to most engineers. It is in the high-speed electronic computer field that the technological revolution has been taking place. Fundamental changes have occurred in both equipment and methods of analysis.

In the computer equipment field, the old argument, "analog vs digital", is now rarely heard. Currently in its adolescence, the electronic computer industry has begun to understand the merits and limitations of its equipment and has even directly connected the two types in several systems, so as to take advantage of the unique features of each. In the methods field, numerical analysis has become a major mathematical discipline. The types of computation which must

be performed on test data are as varied as the subjects of the tests. There are, however, certain types which, being common to many fields, appear fairly frequently. Matrix inversion, numerical integration, and curve fitting are typical of these broad classes.

Matrix inversion

While matrix algebra had been used for many years in theoretical work, its extensive application to numerical data analysis awaited the electronic digital computer. With the present speeds of these machines, matrices of order 100 and larger can be handled in a reasonable period of time. However, as speed problems are being overcome, other types of problems appear. One of the most serious is the problem of "round-off error". When two numbers of n digits each are multiplied, the product, in general, contains $2n$ digits. Because of memory register limitations, however, it is frequently necessary to store less than the full $2n$ digits. The allowed number of high-order digits is selected, with appropriate round-off in the least significant position. When this product is used in later steps, the round-off error propagates. In lengthy calculation sequences, the error propagation can completely invalidate the final answer. Since large-scale matrix inversion involves long sequences of arithmetic operations, the problem there is particularly severe. This can be illustrated by means of a simplified example. Before proceeding with the numerical aspects of the example, however, it is worthwhile to give the matrices physical significance.

Aerodynamic wind tunnel measurements are usually made by means of strain gage bridges. The change in voltage across a bridge, due to its distortion under an applied force, is related to that force. In order to calculate the unknown force or load, the bridge must first be calibrated. This can be done by applying a series of known forces to the bridge and measuring the resulting voltages. Then, when a test voltage is later measured, the equivalent force can be read from the calibration curve.

In practice, it is frequently desirable to use multi-bridge balances. For example, a three-component balance might measure three orthogonal forces or two forces and a moment. When such balances are used, the calibration procedure is somewhat more complex than for a single bridge because of the unavoidable interaction between the balance components. Thus, a three-component balance is calibrated by applying known loads (forces or moments as the case may be) to a single component and measuring the resulting voltage change on all three components. This is repeated for each bridge. Thus, nine calibration curves are obtained.

For simplicity, assume that each of these nine curves is linear. That is, assume that the voltage increment for each component is directly proportional to the physical load applied to any component. If the three components are designated 1, 2, 3, then the voltage increment measured on component 1 due to load on component 3 is actually the slope of the straight-line curve plotted for this pair of terms in the calibration procedure. This slope or tangent value can be written a_{13}. The calibration relationships between the measured voltages v_1, v_2, v_3 and the applied loads l_1, l_2, l_3 are then given as follows:

$$
\begin{aligned}
v_1 &= a_{11}l_1 + a_{12}l_2 + a_{13}l_3 \\
v_2 &= a_{21}l_1 + a_{22}l_2 + a_{23}l_3 \\
v_3 &= a_{31}l_1 + a_{32}l_2 + a_{33}l_3
\end{aligned}
$$

During an actual test, the voltages are known and the loads must be computed. This would require repeated solution of the above equations. Matrix algebra can be used to ease the task.

Fortunately, if a balance receives careful handling, it need only be calibrated infrequently, perhaps once per year. Thus, the slopes a_{11}, a_{12}, . . ., a_{33} remain constant over a fairly long time period. This adds to the convenience of employing matrix manipulation techniques.

By inverting the matrix whose elements are the slopes, the problem of computing unknown loads from measured test voltages is reduced to a simple series of multiplications and additions. Consider the inversion of the following matrix, keeping in mind that a matrix is merely an array of meaningful numbers which can be manipulated for arithmetic convenience.

$$
\begin{bmatrix}
a_{11} & a_{12} & a_{13} \\
a_{21} & a_{22} & a_{23} \\
a_{31} & a_{32} & a_{33}
\end{bmatrix}
$$

For ease of further explanation, call this matrix A, and assign the following numerical values:

$$
A = \begin{bmatrix} 4.2635 & 1.6484 & 2.3311 \\ 6.0187 & 8.5506 & 7.8506 \\ 2.1933 & 5.3179 & 3.0124 \end{bmatrix}
$$

Assume that the matrix will be inverted on a computer capable of giving a ten-digit product, but storing five-digit numbers. Although many mathematically sophisticated matrix inversion techniques have been developed, the one most commonly used is the elimination technique. The example matrix will be inverted by this method.

The basic idea of elimination is quite simple. By subtraction of multiple of rows from each other and division of rows by constants, matrix A can be transformed into the unit matrix 1. If the same operations are simultaneously performed on the unit matrix, this will end up as A^{-1}, just as A ends up as 1.

$$
\begin{array}{cc}
A & 1 \\
\begin{bmatrix} 4.2635 & 1.6484 & 2.3311 \\ 6.0187 & 8.5506 & 7.8506 \\ 2.1933 & 5.3179 & 3.0124 \end{bmatrix} &
\begin{bmatrix} 1.0000 & 0 & 0 \\ 0 & 1.0000 & 0 \\ 0 & 0 & 1.0000 \end{bmatrix}
\end{array}
$$

Divide row 1 by a_{11} (where the two-digit subscript denotes the row and column in which the element is located).

$$
\begin{bmatrix} 1.0000 & 0.3866 & 0.5468 \\ 6.0187 & 8.5506 & 7.8506 \\ 2.1933 & 5.3179 & 3.0124 \end{bmatrix}
\begin{bmatrix} 0.2345 & 0 & 0 \\ 0 & 1.0000 & 0 \\ 0 & 0 & 1.0000 \end{bmatrix}
$$

Subtract a_{21} times row 1 from row 2 and a_{31} times row 1 from row 3.

$$
\begin{bmatrix} 1.0000 & 0.3866 & 0.5468 \\ 0 & 6.2238 & 4.5596 \\ 0 & 4.4700 & 1.8131 \end{bmatrix}
\begin{bmatrix} 0.2345 & 0 & 0 \\ -1.4114 & 1.0000 & 0 \\ -0.5143 & 0 & 1.0000 \end{bmatrix}
$$

Replace row 1 by row 2, row 2 by row 3, row 3 by row 1. Then replace column 1 by column 2, column 2 by column 3, and column 3 by column 1. That is, move the elements up and to the left.

$$
\begin{bmatrix} 6.2238 & 4.5596 & 0 \\ 4.4700 & 1.8131 & 0 \\ 0.3866 & 0.5468 & 1.0000 \end{bmatrix}
\begin{bmatrix} 1.0000 & 0 & -1.4114 \\ 0 & 1.0000 & -0.5143 \\ 0 & 0 & 0.2345 \end{bmatrix}
$$

Repeat the same operations.

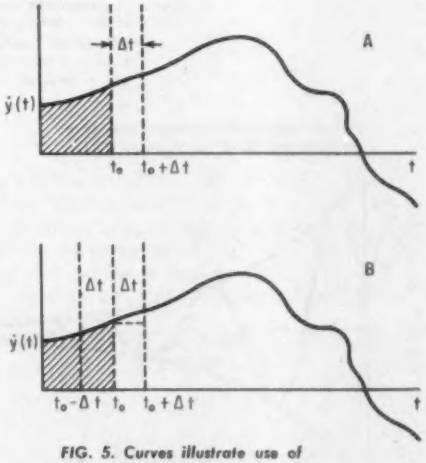


FIG. 5. Curves illustrate use of Euler integration formula.

$$\begin{bmatrix} -1.4616 & 0 & 0 \\ 0.2636 & 1.0000 & 0 \\ 0.7326 & 0 & 1.0000 \end{bmatrix} \quad \begin{bmatrix} 1.0000 & 0.4995 & -0.7183 \\ 0 & 0.3222 & -0.0621 \\ 0 & -0.2268 & 0.1607 \end{bmatrix}$$

And repeat the same operations once more. That is, the cycle of operations is carried out n times for an n-by-n matrix.

$$I \qquad\qquad A^{-1}$$

$$\begin{bmatrix} 1.0000 & 0 & 0 \\ 0 & 1.0000 & 0 \\ 0 & 0 & 1.0000 \end{bmatrix} \quad \begin{bmatrix} 0.4123 & -0.1916 & 0.1804 \\ 0.0235 & -0.1993 & 0.5012 \\ -0.3417 & 0.4914 & -0.6842 \end{bmatrix}$$

As an indication of the effects of round-off, the same matrix can be inverted assuming that a six-digit product can be obtained, but a three-digit number stored. The resulting inverse is

$$\begin{bmatrix} 0.41 & -0.20 & 0.19 \\ 0.02 & -0.21 & 0.50 \\ -0.33 & 0.50 & -0.69 \end{bmatrix}$$

It can be seen that in the two inverse matrices some elements differ in the first non-zero figure. In work with larger matrices, the round-off effects, as mentioned earlier, are even more severe. Although this example is not quite a true simulation of a round-off problem, it does permit the use of a small matrix to illustrate the severity of such effects.

It might be of interest now to point out the physical significance of the resulting inverse, as a conclusion to the previous discussion on wind tunnel balances. The elements of A were a_{ij}. The elements of A^{-1} can be called b_{ij}. The equations to be used in computing loads from voltages after a test can then be written as follows.

$$\begin{aligned} l_1 &= b_{11}v_1 + b_{12}v_2 + b_{13}v_3 \\ l_2 &= b_{21}v_1 + b_{22}v_2 + b_{23}v_3 \\ l_3 &= b_{31}v_1 + b_{32}v_2 + b_{33}v_3 \end{aligned}$$

It is seen that calculation of the load values is now a simple process, and does not require the solution of a set of simultaneous equations for each new set of voltage readings (i.e., for each new test condition). Since the values of b_{ij} are functions only of the a_{ij} terms, and these are constant over many tests, the inversion process need be carried out only approximately once per year.

Numerical integration

Numerical integration is used in a variety of computational areas. In the analysis of airborne and space-borne vehicles, flight paths written in differential equation form are calculated by integration. In the analysis of control systems, Fourier and Laplace transforms are expressed as integrals. And in the analysis of radioactive shielding, certain statistical quantities must be integrated in order to compute required material thicknesses, mean molecular paths, and other pertinent quantities.

In each of the above applications, the integrand is, in practice, expressed as a series of numerical values rather than as a nice integrable mathematical function. Flight path integration involves rate gyro, accelerometer, and other instrument readings, for example, while Fourier transform integrand generally includes readings from plotted test data curves, multiplied by periodic functions of the frequency.

A consideration of several elementary numerical integration formulas will provide a graphical analogy to the numerical processes. Consider the simple Euler integration formula, derived from the first two terms of the Taylor series expansion.

$$y(t_o + \Delta t) = y(t_o) + \Delta\, t\dot{y}(t_o)$$

where $y(t_o)$ is the derivative of y at point t_o. Assume Figure 5A to be a plot of $y(t)$. The shaded area under the curve represents the definite integral

$$y(t_o) = \int_o^{t_o} \dot{y}(t)\, dt$$

To obtain the area for the next segment, the Euler formula assumes the segment to be rectangular in shape, with width Δt and height $\dot{y}(t_o)$. Thus, it is assumed that the following approximation holds:

$$y(t_o\ \Delta t) = \int_o^{t_o+\Delta t} \dot{y}(t)\, dt \cong y(t_o) + \Delta t\dot{y}(t_o)$$

A somewhat better approximation is known as linear extrapolation. In Figure 5B, the shaded area again represents the integral up to point t_o. The area of the next segment is obtained by assuming that it consists of two parts, a rectangle and a triangle, as shown on the figure. The area of the rectangle is as described above. The triangle has base Δt, but its altitude is assumed to be the same as that of the corresponding triangle in the previous segment. That is, it is assumed that:

$$\dot{y}(t_o + \Delta t) - \dot{y}(t_o) \cong \dot{y}(t_o) - \dot{y}(t_o - \Delta t)$$

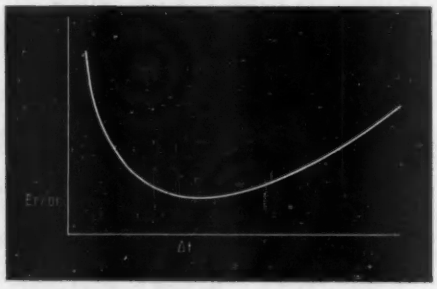
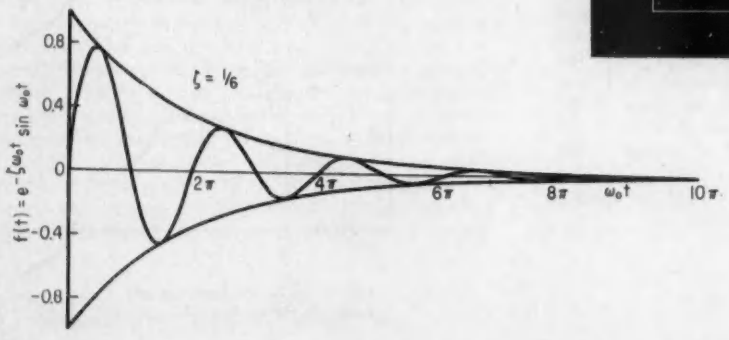


FIG. 6. Curve shows change in integration error at an arbitrary point t as integration interval Δt is varied.

FIG. 7. Exponentially-damped sine wave serves as test results for example in text.



This assumption leads to the following approximation for the area to the point $t_o + \Delta t$.

$$y(t + \Delta t) = \int_{o}^{t_o+\Delta t} \dot{y}(t)\, dt \cong$$

$$y(t_o) + \Delta t \dot{y}(t_o) + \frac{\Delta t}{2}\left[\dot{y}\,(t_o) - \dot{y}(t_o - \Delta t)\right]$$

More refined integration techniques, which take into account higher-order effects, are, of course, necessary in exacting analyses. In particular, Project Mercury, the "man in orbit" program, will need extremely elegant numerical techniques in order to properly predict, for example, the point in the trajectory at which to "kick" the satellite out of orbit so as to have its human cargo descend to the desired location.

In numerical integration, as in matrix manipulation, the effects of round-off can be treacherous. For a typical simple numerical integration technique, Figure 6 shows the qualitative change in the integration error at an arbitrary point t, as the integration interval, Δt, is varied. The error, of course, decreases as the interval is decreased, to a certain point. When the integration interval is small, the number of calculation cycles required to reach point t is large. Thus a greater number of intermediate terms must be rounded-off, and the error in $y(t)$ increases.

More elegant integration formulas tend to postpone the sharp rise in the error curve, but it still remains a matter of grave concern to the analyst.

In frequency-response studies, a different type of error often causes difficulties. Assume that dynamic test data have been recorded either on magnetic tape or on an oscillograph. For convenience of analysis, assume further that one of the time traces can be represented as the exponentially-damped sine wave,

$$f(t) = e^{-\zeta\omega_o t} \sin \omega_o t$$

plotted on Figure 7. It is enlightening to study the effect of stopping the test after a finite number of oscillation cycles.

The Fourier transform, $F(\omega)$, of the above function can be represented by an amplitude $A(\omega/\omega_o)$ and a phase angle $\phi(\omega/\omega_o)$ where ω_o is the natural frequency of the oscillation. If the entire infinite oscillation is considered, the Fourier transform is

$$20 \log A_\infty = -10 \log \left\{ \zeta^4 + 2\zeta^2[(\omega/\omega_o)^2 + 1] + [(\omega/\omega_o)^2 - 1]^2 \right\}$$

$$\phi_\infty = \tan^{-1} \frac{-2\zeta(\omega/\omega_o)}{\zeta^2 + 1 - (\omega/\omega_o)^2}$$

where the amplitude has been converted to decibels. If only $n/2$ complete oscillation cycles are recorded, the resultant transform is given by

$$20 \log A_{n/2} = 20 \log A_\infty + 10 \log \left[1 + e^{-2n\pi\zeta} - 2(-1)^n e^{-n\pi\zeta} \cos n\pi(\omega/\omega_o)\right]$$

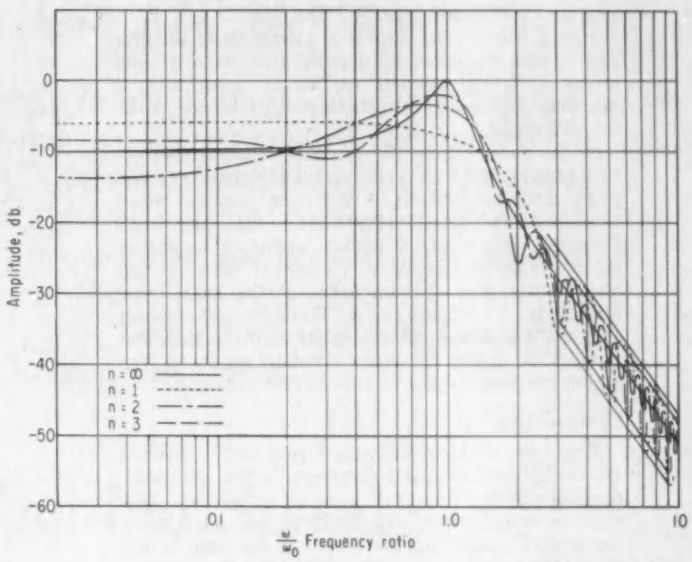


FIG. 8. Graph of amplitude vs frequency ratio for various damping ratios

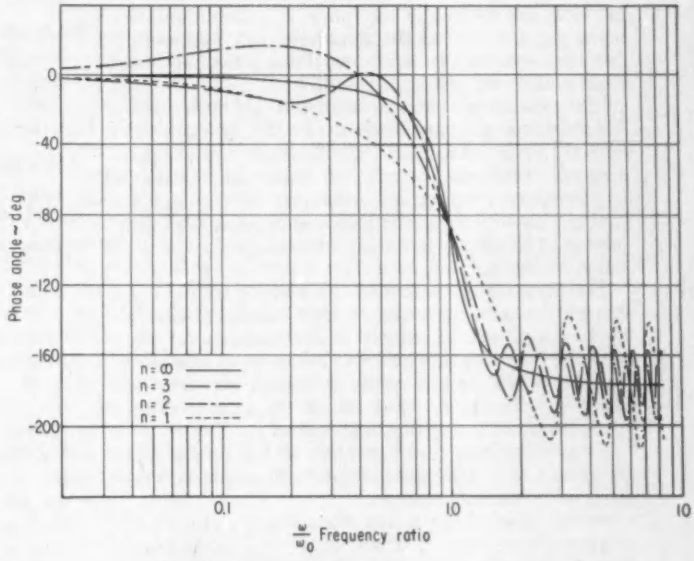


FIG. 9. Phase plot corresponding to the results depicted in Fig. 7.

$$\phi_{n/2} = \phi_\infty + \tan^{-1} \frac{(-1)^n e^{-n\pi\zeta} \sin n\pi(\omega/\omega_o)}{1 - (-1)^n e^{-n\pi\zeta} \cos n\pi(\omega/\omega_o)}$$

It is seen that the amplitude for the finite number of cycles can be obtained from that for the infinite number by the addition of a periodic correction term. This term has both an upper and a lower limit as well as a mean line shift which is dependent on the number of cycles and the damping constant, but independent of the frequency ratio.

The phase angle for the finite case can also be written as the sum of the phase angle for the infinite

case plus a bounded periodic correction.

Figure 8 shows the amplitude plotted in decibels for the infinite exponentially damped sine wave, as well as for ½, 1, 1½ complete oscillation cycles, using a damping ratio, ζ, of $\frac{1}{6}$. Figure 9 shows the corresponding phase plot.

It can be seen from the preceding analysis that use of a finite number of cycles makes the amplitude and phase angle oscillate about their true values. One of the reasons for this phenomenon is the sharp high-frequency input which occurs when an oscillatory curve is suddenly forced to a constant value. It can also be seen that the amplitude at the natural frequency, ω_n, is a function of n. Thus, the test engineer and the numerical analyst must record a sufficient number of cycles to insure accurate results at the higher frequencies and at the natural frequency.

Curve fitting

The basic problem in curve fitting can be worded as: "What mathematical expression, when evaluated, provides the best fit to the given set of points?" This problem statement is deceptively simple. Its entire significance hinges on the meaning attached to the words, "best fit". Is the best fit obtained, for example, when the mathematical curve passes through the greatest number of points regardless of how closely it approximates the others; or when the largest deviation between the curve and any point is a minimum; or when the total of all the deviations is a minimum? And, in summing the deviations, if this is the criterion, should algebraic sign be included?

Mathematicians have puzzled over all these questions for many years. Despite this, no generally accepted single definition of "best fit" has been evolved. However, because of these mathematical deliberations a better understanding of the significance of each proposed definition does exist, and different definitions have been found preferable in different applications.

For purposes of illustrating curve fitting techniques, one of the more common of these methods will be used. This method, which is one variation of the so-called "least squares" theory, attempts to minimize the sum of the squares of the deviations between the curve and the points. The use of the squares eliminates the question of algebraic signs.

First, a mathematical derivation of the system will be given. This will be followed by a simple but instructive numerical example.

Assume a set of test points whose x and y values are, respectively, $x_1, x_2, \ldots, x_n$ and $y_1, y_2, \ldots, y_n$. It is desired to find the polynomial which best fits the data, in the above "least squares" sense. The polynomial can be written:

$$y = a_1 + a_2x + a_3x^2 + \cdots + a_mx^{m-1} = \sum_{j=1}^{m} a_jx^{j-1}$$

where $m \leq n$. For convenience, let $m = n$, and let U_i be the deviation at point i.

$$\therefore U_i = \sum_{j=1}^{n} a_jx_i^{j-1} - y_i, \quad i = 1, 2, \ldots, n$$

It is now desired to minimize the sum of the squares of the U_i.

$$\text{Let } W = \sum_{i=1}^{n} U_i^2$$

To minimize W, it is necessary to take the derivative of W with respect to each U_i, and set these n derivatives equal to zero simultaneously. The resulting values of $a_1, a_2, \ldots, a_m$ will define the best "least squares" polynomial.

As a simple example, consider the following x, y values.

x	y
$x_1 = 2$	$y_1 = 5$
$x_2 = 4$	$y_2 = 9$
$x_3 = 6$	$y_3 = 13$

That curve of form $a_1 + a_2x + a_3x^2$ which best fits these test points will now be found. Note that here $m = n = 3$.

$$U_1 = a_1 + a_2x_1 + a_3x_1^2 - y_1$$
$$U_2 = a_1 + a_2x_2 + a_3x_2^2 - y_2$$
$$U_3 = a_1 + a_2x_3 + a_3x_3^2 - y_3$$
$$W = U_1^2 + U_2^2 + U_3^2$$
$$\frac{dW}{dU_1} = 2U_1 + 2U_2\frac{dU_2}{dU_1} + 2U_3\frac{dU_3}{dU_1}$$
$$\frac{dU_2}{dU_1} = \frac{\partial U_2}{\partial a_1}\frac{da_1}{dU_1} + \frac{\partial U_2}{\partial a_2}\frac{da_2}{dU_1} + \frac{\partial U_2}{\partial a_3}\frac{da_3}{dU_1}$$

Similarly for $\frac{dU_3}{dU_1}$. Now set $\frac{dW}{dU_1} = 0$.

$$(a_1 + a_2x_1 + a_3x_1^2 - y_1) + (a_1 + a_2x_2 + a_3x_2^2 - y_2)\left(1 + \frac{x_2}{x_1} + \frac{x_2^2}{x_1^2}\right) + (a_1 + a_2x_3 + a_3x_3^2 - y_3)\left(1 + \frac{x_3}{x_1} + \frac{x_3^2}{x_1^2}\right) = 0$$

Evaluating this and the terms obtained by setting $\frac{dW}{dU_2} = 0$ and $\frac{dW}{dU_3} = 0$ yields three simultaneous equations in a_1, a_2, a_3.

$$21a_1 + 108a_2 + 584a_3 - 237 = 0$$
$$15a_1 + 72a_2 + 388a_3 - 159 = 0$$
$$41a_1 + 156a_2 + 680a_3 - 353 = 0$$

The solution is $a_1 = 1$, $a_2 = 2$, $a_3 = 0$. Therefore, the best second-degree polynomial for fitting the given data is:

$$y = 1 + 2x$$

When large masses of data are involved, the use of an electronic digital computer is essential for handling the resulting calculations in a reasonable time.

In employing curve-fitting techniques, there is a considerable danger of inadvertently invalidating the results of a costly and time-consuming test. To avoid this, certain steps can be taken. For example, the optimum "best fit" criterion should be selected. Also the data to be fitted should be screened. This is of vital importance. If the data contains occasional "wild" points (caused, say, by an intermittent spurious signal), the resulting curve-fit formula will be adversely affected, since it will attempt to fit these scattered values on an equal basis with the valid ones.

These pitfalls, and those discussed earlier, can largely be avoided through early cooperation and careful study by the members of the testing team. But, this can be accomplished only if the team possesses the full spectrum of required skills—those of the project engineer, those of the instrumentation engineer, and those of the computer specialist.

Case Studies of Test

The preceding articles laid the groundwork. They showed the forms in which systems can be manipulated and tested; emphasized the importance of test planning to obtain maximum information for minimum cost; and discussed the common testing functions of sensing, transmission, recording, and processing. These 12 case histories demonstrate test techniques at work across the scope of industry and the military. Each of the examples highlights one particular aspect of test — and in sufficient detail to permit extrapolation into the reader's own application area.

#1 Skeleton Machine Speeds Control Tests

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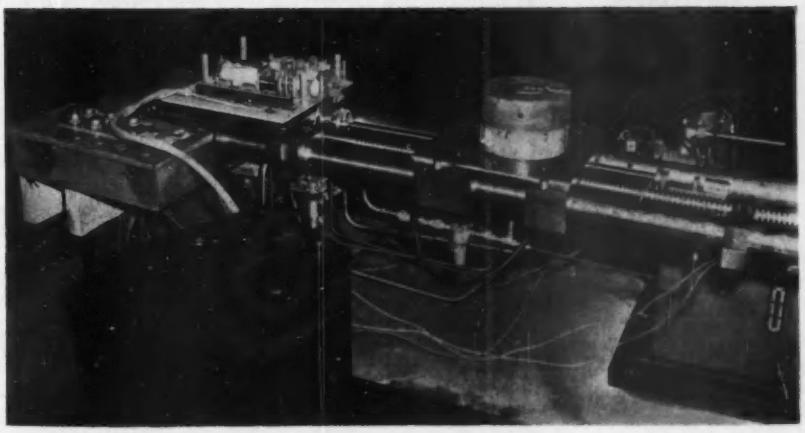
With the increasing application of servo drives to machine tools, it has become obvious that the actuating system and the input system must be compatible with each other for optimum results. Such compatibility is hard to achieve when automatic controls, and numerical positioning systems particularly, are added to existing equipment. Therefore, there is a tendency now to initiate the design of new machines and new controls simultaneously. Although this practice certainly solves the compatability question, it creates a new problem for the control engineer: the machines are not available for test early enough to aid in design trials. Such tests are essential, too, because machine tools typically work under a wide range of speeds, friction loads, and cutting loads so that control performance is difficult to predict on the basis of analysis alone.

In view of this, it would be helpful to have available in the planning stages of a new system some kind of simulator that would make it unnecessary to build an experimental machine to determine its characteristics. The breadboard model or simulator shown in Figure 1 is such a device. The carriage is a simple slide traveling on two ground bars that represent the ways of the machine. The slide is operable under various lubrication conditions and carrying a wide variety of deadweights to simulate carriage and tool loads. In addition, the slide can be bucked by two cylinders on the right end of the ways. By means of a hydraulic pressure-regulating valve, this opposing load can be scaled to duplicate the resistance of a drill, or the feed load of a cutting tool as it becomes dull.

The slide is driven by either of two types of hydraulic servos, one of which includes a cylinder (atop the left end of the structure). Since hydraulic servo systems using cylinders and servovalves are inherently nonlinear and because of the compressibility factor, the lengths of stroke, speeds, and loads that can be stably driven by this means are limited. The second servo consists of a power leadscrew driven by a constant-volume hydraulic motor. Typically, the cylinder is used for short strokes and small masses and the fluid-motor drive for heavy loads and long strokes.

In either mode of operation, the servo valve is actuated by the measuring leadscrew (behind the power leadscrew) that engages a nut underneath the carriage. Its initial rotation displaces the leadscrew endwise in the nut and shifts the servovalve to which it is coupled. Thus, oil is ported to either the cylinder or fluid motor to drive the slide in the follow-up direction. The input to the measuring leadscrew can be from any of a variety of systems breadboarded and mounted at the left.

FIG. 1. This "dummy" lathe permits designers to test control systems before actual machines are available



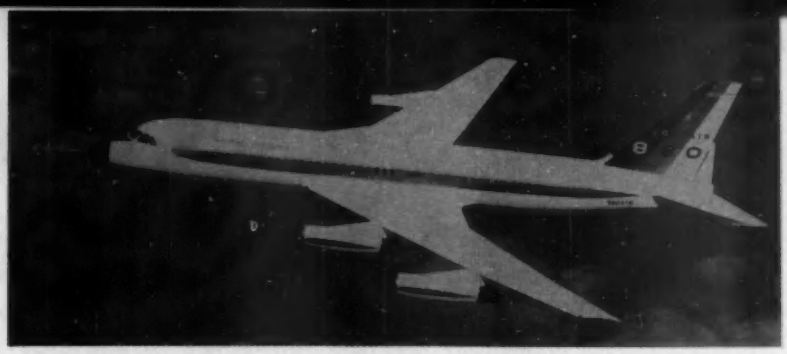


FIG. 1.
Convair 880 during flight test.

#2 Flight Testing Control Systems on the 880

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Convair, San Diego

Control system testing on the new Convair 880 Jet Liner—a high subsonic speed aircraft to serve intermediate and intercontinental routes from existing metropolitan airport runways—is about half completed. Before the 880 is certified by the Federal Aviation Agency, the control system will undergo at least 300 hours of flight test over a 10-month period. First step in this program was to set up a planning sequence:

1. Establish the desired data and measurements pertaining to control system functioning and airplane response characteristics.
2. Select test equipment for recording control system data.
3. Establish test inputs required, test procedures, and conduct test operations.
4. Analyze and interpret data.

Here's how the sequence has evolved for flutter and stability and control testing, which proceed simultaneously because they have much instrumentation in common.

Flutter tests

Flutter is a mechanical oscillation in a flight structure. It is distinguished from vibrations and stress by the frequency spectrum of the oscillations, which normally occur in the range of five to 200 cps with a sinusoidal characteristic and low damping ratio. (Vibrations cover a wide frequency spectrum, are of relatively constant amplitude, have many frequency components, and have a high damping coefficient. Stress is a static or quasistatic condition caused by loading, flight maneuvers, or other slowly varying conditions.) Serious flutter can tear an aircraft surface apart.

During flutter testing, the airplane is excited by two separate methods. Two inertial shakers, one located on each horizontal stabilizer, excite the airframe sinusoidally. The other is pilot controlled excitation; the pilot merely "bangs" the control wheel, column, or rudder pedal.

To obtain the data for flutter tests, test engineers mount three different types of instruments on the airplane. First, accelerometers are located at key possible trouble spots: 1) on wing spars—four accelerometers with a recording range of plus or minus 10 g vertically and a frequency response of 0-50 cps; 2) on engine pods—eight accelerometers; and (3) on the empennage (tail)—six accelerometers, four on the horizontal and two on the vertical stabilizer.

Second, position transducers measure the movement of important surfaces. Seven main areas are studied: 1) pilot's control wheel, column, and rudder pedals; 2) left and right elevator and elevator control tabs; 3) horizontal stabilizer; 4) rudder, rudder trim tab, and aileron control tab; 5) left and right aileron, aileron trim tab, and aileron control tab; 6) left and right inboard and outboard spoilers; and 7) wing flaps.

Finally, other instruments measure horizontal stabilizer shaker frequency and amplitude, airspeed, altitude, and ambient temperature.

Data from all these instruments feed an airborne magnetic tape recording system. A 14-track, 1-in. tape unit, it provides standard frequency modulation for each track, which can record the output of eight frequency modulated oscillators. In this way, 112 continuous functions can be recorded.

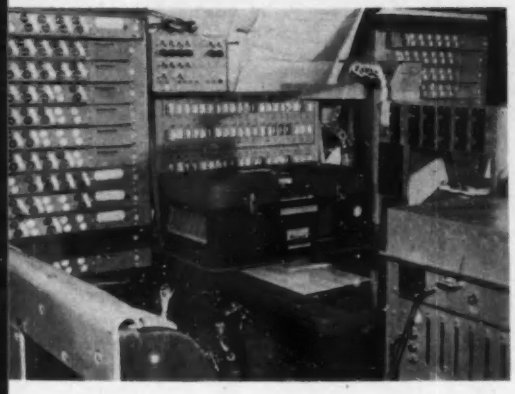
In addition, certain key measurements are telemetered to a ground monitoring station so that ground-based engineers can watch airframe and control system responses during a test. This technique improves flight crew safety during the test and speeds up testing because test engineers can grant a clearance for expanded testing while the flight is in process. In fact, it has already reduced flutter program flight requirements for the 880 test program by 75 hours.

Because the variables of flutter testing are mostly fast changing, Convair selected an FM/FM telemetering system. Two radio frequencies are used; ten frequency modulated subcarriers serve as inputs to the frequency transmitter. On the ground the telemetered signal is simultaneously tape recorded and displayed on direct writing recorders for monitoring purposes. The ground-recorded tape serves as backup for the airborne recorder. If a disastrous failure should occur, resulting in the loss of the aircraft, the ground tape would serve as the prime source of data to explain the accident.

The shakers, which excite the tail surface in flutter tests, were Convair developed and consist essentially of a closed loop servo system to control the movement of two reciprocating masses (Figure 4).

Each shaker can operate in man-

FIG. 2. *Inside the 880, a 14-channel airborne magnetic tape unit (center) records dynamic variables during flutter and stability and control system tests.*



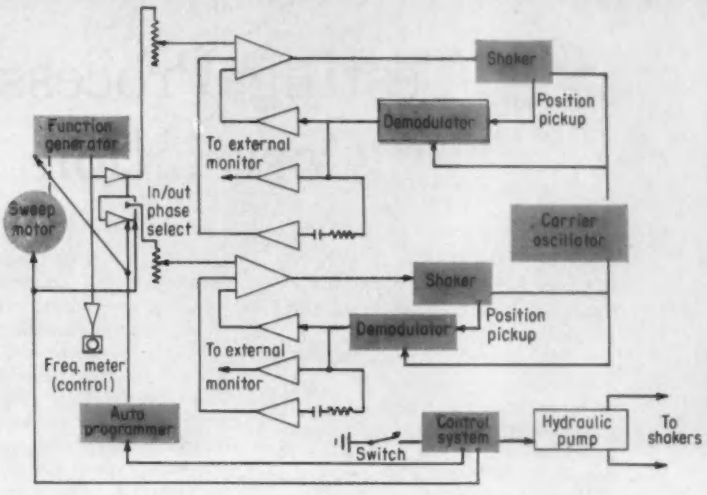


FIG. 4. *Shakers for flutter testing.*

ual or automatic mode. In the manual mode, the shakers sweep through a specified frequency range at a programmed rate of sweep and at a programmed shaker force; the phasing of the shakers has to be selected (either symmetric or antisymmetric) as does the sweep cycle (ascending or descending frequency). In the automatic mode of operation, decay responses are measured. When various frequencies are pre-selected, the shakers will excite the airplane at a given frequency for a specified time, next stop for a specified time, and then step to the next frequency.

The flutter test is made at several speeds and at several different altitudes to demonstrate that the airplane is free from flutter over its design envelope. Tests usually start at relatively low speeds at the highest altitude chosen. Then, tests at lower altitudes are made so that the equivalent speed at high altitude is not exceeded. Repeat runs are accomplished as often as control system changes require them.

During flight the ground crew checks shaker operation through the telemetry system, requests repeat measurements, informs the crew of satisfactory run completion, and estimates damping coefficients from decay records.

When a flutter test flight is completed, the tape record is removed from the airplane recorder and is processed by playing it back through appropriate discriminators. Various low pass and band pass filters screen out extraneous frequency responses —particularly from vibrations and stress—during playback. The end product is an oscillograph trace. The engineering objective of flutter tests is to produce plots of damping coefficients vs airspeed and Mach number for all significant vibration modes at various altitudes. From these, the engineers can prove the aircraft is free from flutter.

Stability and control testing

The purpose of stability and control testing is to measure how the flight controls perform through the entire operating range of the airplane. It means documenting airplane response characteristics while a large number of variables change: gross weight, altitude, airspeed, Mach number, engine power, and airplane center of gravity.

Testing procedures vary with specific measurements. The Federal Aviation Agency sets rigid requirements and test procedures for each.

In many of the stability and control tests, conformance with requirements is assessed on the basis of how big are the control forces reacting to the pilot's commands and how the control forces react to changes in speed and altitude.

Some of the data required for stability testing is static-type information, involving relatively slow changing variables. Such data are recorded by a photopanel recorder (continuous photographing of instruments). The photopanel also serves as a convenient visual reference for flight crew monitoring of test results, from which the crew can make in-flight decisions about the test program.

The photopanel consists of an internally lighted box containing an instrument panel accommodating 44 standard size aircraft instrument mounting holes, a 35 mm camera, and a one-way reflecting glass. Mounted on the back of the concave shaped panel, the camera photographs (through an aperture in the panel) a panel image projected on the reflecting glass mounted ahead of the panel. The reflecting glass, however, permits straight-through viewing from the exterior by the test engineer who monitors the instruments.

The camera can be controlled so it operates in a number of modes: single frame, multi-frame, or continuous (cine, 16 frames per sec).

The variables that are measured on the photopanel are listed in the table. To measure dynamic variables, a setup similar to that for flutter testing is used. The same instruments measure variables and feed an airborne magnetic tape recorder.

Variables Recorded on Photopanel

Position
Pilot's control wheel, column, and rudder panels
Aileron and aileron control tab
Rudder and rudder control tab
Elevator and elevator control tab
Left and right inboard and outboard spoilers
Stabilizer
Left and right wing flaps

Control Force
Pilot input forces to the control wheel, column, and rudder pedals

Airplane Attitude
Angle of attack
Angle of sideslip
Lateral attitude
Longitudinal attitude

Miscellaneous
Standard and alternate ship's system airspeed and altitude
Test system airspeed and altitude
Cabin altitude
Gross weight—(direct indication from computer)
Ambient temperature
Landing gear lift-off lights
Data correlation indicator (for correlation of photopanel data with tape recorder data)

#3 Testing Process Performance by Correlation

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When the performance of a group of furnaces in England was investigated, control engineers used correlation methods of system analysis to determine the control dynamics of a 250-ton, open-hearth, steel melting furnace, equipped with automatic roof-temperature control. By automatically maintaining the temperature, the control speeds the refining process and extends furnace roof life. During the initial stages of melting, until the roof temperature exceeds 1,645 deg C, the furnace operates with a constant rate of oil-flow. Then the automatic roof control maintains the roof-temperature at 1,645 deg C, within plus or minus 10 deg.

In the control loop, Figure 1, the rate of oil flow into the furnace is controlled by an electrohydraulic P-I controller. An error signal, derived by the deviation of roof temperature, T, from the preset value of 1,645 deg C., operates the controller. At the same time, ratio controllers maintain the correct rates of airflow for combustion and steam flow for atomization. These units are run by a current from the oil-flow metering circuit.

The first step in determining the furnace transfer-function by correlation was to break the automatic loop and operate on manual control. If this is not done, the perturbations in temperature arising from fluctuations of conditions within the furnace constitute the principal source of disturbances in the system. Under these conditions, when F (fuel flow) is correlated with temperature, the inverse of the controller transfer-function is obtained instead of the furnace transfer-function.

With the furnace controlled manually, the roof temperature was about 1,645 deg C. Flow and temperature were recorded on servo-operated pen-recorders with a chart speed of $\frac{1}{2}$ in. per sec. Typical records are shown in Figure 2. The auto-correlogram of flow, ϕ_{FF}, and the cross-correlogram between flow and temperature, ϕ_{FT}, were calculated by digital computer (Figure 3). Cross-correlation eliminates any components of T that are not due to F; it is a measure of the average linear dependence of T upon F.

Best approximation to the furnace transfer-function (Ref. 1) is given by the equation

$$\phi_{FT}(\tau) = \int_0^\infty W(t)\,\phi_{FF}(\tau - t)\,dt \qquad \text{for } \tau > 0$$

which has to be solved for the weighting function $W(t)$. To estimate the transfer-function, ϕ_{FT} and ϕ_{FF} were reproduced as voltage waveforms. The voltage corresponding to ϕ_{FF} was then fed into a general-purpose analog computer, set to simulate a variety of simple transfer functions which were adjusted until the output gave the closest fit to the function ϕ_{FT}. The relationship

$$\frac{T}{F}(s) = \frac{0.32}{1 + 2.1s} \quad \frac{\text{deg C}}{\text{gal per hour}}$$

where S is the Laplace transform, fits the data closely.

In a similar way, the controller response was determined. By combining the two, the overall response of the installation was obtained.

This method of analysis has great potential for testing industrial processes, particularly for determining the characteristics of existing plants to which it is proposed to fit automatic controls. By recording data digitally, the whole process, including correlation and transfer-function estimation, can be done on a digital computer. This investigation was conducted in co-operation with the British Iron and Steel Research Association, Messrs. John Summers and Sons, Ltd., and Messrs. Evershed and Vignoles, Ltd.

REFERENCE

1. *THE EXPERIMENTAL DETERMINATION OF SYSTEM TRANSFER FUNCTIONS FROM NORMAL OPERATING DATA*, J. G. Henderson and C. J. Pengilley, "British I.R.E. Journal", Vol. 18, March 1958, pp. 179-186.

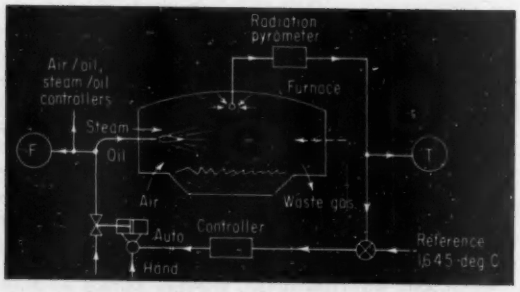
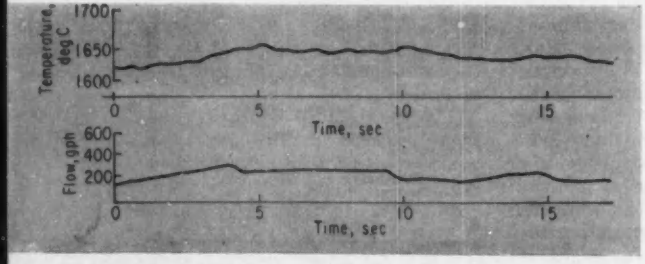


Figure 1. Roof temperature control system.

Figure 2. Flow and temperature records.



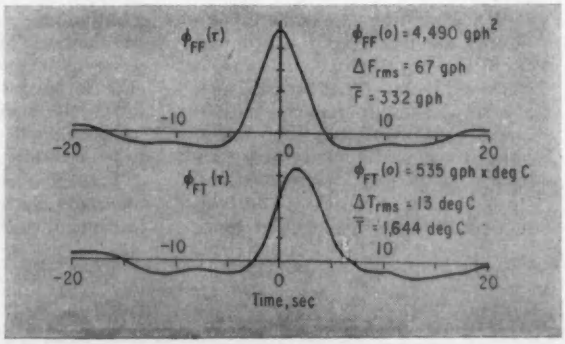


Figure 3. Auto- and cross-correlograms.

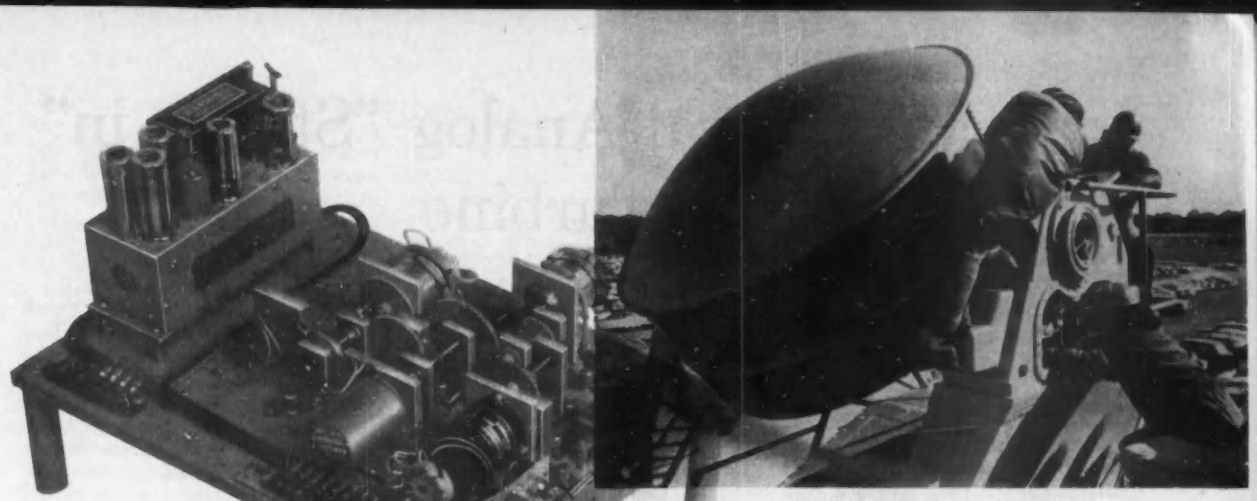


FIG. 1. Workmen make final adjustments on antenna of Navy's new guidance radar for Terrier missile.

FIG. 2. Breadboarded follow-up servo used in testing guidance system.

#4 Breadboarded Tester Subs for Guidance Computer

DON ARUNDEL
Servo Corp. of America

Standard precision breadboard kit components integrated in a test stand have helped speed the check out of the new AN/SPG-55 guidance radar system, Figure 1, that commands the Navy's "Terrier" surface-to-air missile. The system, designed and developed by Sperry Gyroscope Co., is being put through regular "shakedown" maneuvers at Sperry's MacArthur Field facility, Long Island, New York. The AN/SPG-55 will be installed on fighting ships armed with the latest version of the Terrier missile, which is already operational on two cruisers and on one destroyer. Other ships slated to be armed with Terrier include: two Forrestal-class aircraft carriers, three cruisers, one nuclear-powered guided-missile frigate, and one nuclear-powered aircraft carrier.

The new guidance radar system succeeds the more massive SPQ-5 and SPQ-5A systems, has greater range, and is fully automatic. From the time the target is designated to the radar through the time the radar goes into automatic tracking, the radar operator's sole function is to observe.

Normally, aboard ship, the guidance radar is under the command of a room-sized computer. For test purposes, however, engineers of Sperry's Surface Armament Division wanted a way to eliminate need for the big computer at the test site. The solution was to take out of the computer certain functions that were not part of actual fire control and simulate them through use of some other device.

A function generator and mixer assembly was designed to synthesize the proper type signals for test purposes. This assembly generates the same types of signals that are normally sent to the guidance radar system by the computer; square-wave, ramp, and sinusoidal signals are common forms of computer output. Key component of the function generator and mixer assembly is a breadboarded follow-up servo, Figure 2, which provides the compatible link between generated functions and the radar system under test. The servo assembly is designed to rotate two synchro transmitters and convert scaled voltages into mechanical shaft rotation and angle position.

The follow-up servo is a standard part of the actual control system and would have required initial breadboarding in any event. In this case, however, the breadboarded version was pressed into test service immediately without repackaging. Had the prototype required conventional design and fabrication, it is estimated that cost would have been doubled and assembly delayed several months.

In use, the breadboarded servo proved precise and rugged enough to be made a permanent part of the test stand. With the prototype in breadboard form, retrofits, field alterations, and any required repairs can be made quite simply. Substitutions, and even major system changes, can be accomplished without costly mechanical alterations. The follow-up servo was constructed from SERVOBOARD kits made by Servo Corp. of America.

#5 Mechanical Analog "Stands in" for Steam Turbine

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D. L. REXFORD
General Electric Co.

In G.E.'s Small Steam Turbine Dept., the term governor is used to describe what is actually a complex mechanical-hydraulic feedback control system for speed regulation. Recent years have seen the adoption of sophisticated analytical methods that have aided considerably in governor design. But analysis alone is not sufficient to guarantee that a new governor will have the needed stability and response when it leaves the draftsman's board. Extensive testing of full-scale working prototypes continues to be an unavoidable step in the design process.

The problem has been that such testing on actual turbines is an extremely costly, time-consuming, and unmanageable business. To illustrate, the designer who wishes to schedule a test has to arrange for the set-up of massive turbines (ranging up to 10,000 hp). He must make certain that enough steam will be available for the run, that his instrumentation is installed, and that the "trades" (steamfitters, riggers, etc.) will be standing by to aid in the test. Such involvements—plus the hazardous nature of the tests—prompted the development of an alternate procedure that substitutes a simple, comparatively small mechanical analog for the huge turbines, and cool air for live high-pressure steam.

Governor operation

Figure 1 is a cross-sectional view of a medium-size steam turbine used to drive equipment such as electric generators, pumps, and paper mills. The steam delivered to the turbine buckets is regulated by the valves at top, which are controlled in turn by the governing system shown at the left. The function of the governor is to maintain turbine speed constant, despite variations in the torque loads imposed on the output shaft. The steam valve is opened and closed by a hydraulic cylinder through a pivoted mechanical linkage.

In a typical regulator, oil from a positive-displacement pump, gear driven by the turbine shaft, passes through an orifice to the spring-loaded piston of the valve-operating cylinder. The pressure within this cylinder (hence the amount of opening of the main steam valve) is controlled by a pilot valve in the discharge line from the cylinder. To simplify the understanding of this valve, assume that it consists of a tube operating within a sleeve or bushing. The relative positions of bushing and tube determine the amount of opening of the valve in the cylinder discharge line. A flyball governor, also driven by the turbine shaft, mechanically positions the tube. The bushing is also moveable and is linked to the piston of the valve-operating cylinder.

If the load on the turbine shaft is increased, the speed of the rotor drops. The resulting action of the flyball governor moves the tube up. This decreases oil discharge through the pilot valve and raises the oil pressure in the operating cylinder. This moves the spring-loaded piston so as to further open the main steam valve, restoring the turbine to its set speed. The flyball governor and pilot-valve tube resume their original positions. In the meantime, however, the movement of the piston had caused the pilot-valve bushing to move up. Thus, the cylinder pressure and steam-valve opening are maintained at their new values despite the removal of the error signal (from the flyball governor).

If the process requirements cause an increase in turbine speed, the system acts in reverse. Note that this is a simplified explanation; in actual regulating systems there may be as many as two or three hydraulic pilot stages, with correspondingly more complex mechanical-linkage feedback, Figure 2.

Description of analog

The mechanical-hydraulic analog is designed to operate in the same manner as an actual speed governing system on a turbine. Many of the actual components of the governing system are present in the analog; the principal points of simulation are the turbine and the speed-sensing device. Figure 3 is a schematic diagram of the analog. The operation of the turbine is duplicated by speed simulator 1 and bowl pressure simulator 5. Governor simulator 2 represents the flyball governor. Speed-control mechanism 3 and torque tube and operating cylinder assembly 4 are standard components of an actual governing system.

The speed simulator is intended to introduce into the test set-up reactions equivalent to those that would be generated in an actual tur-

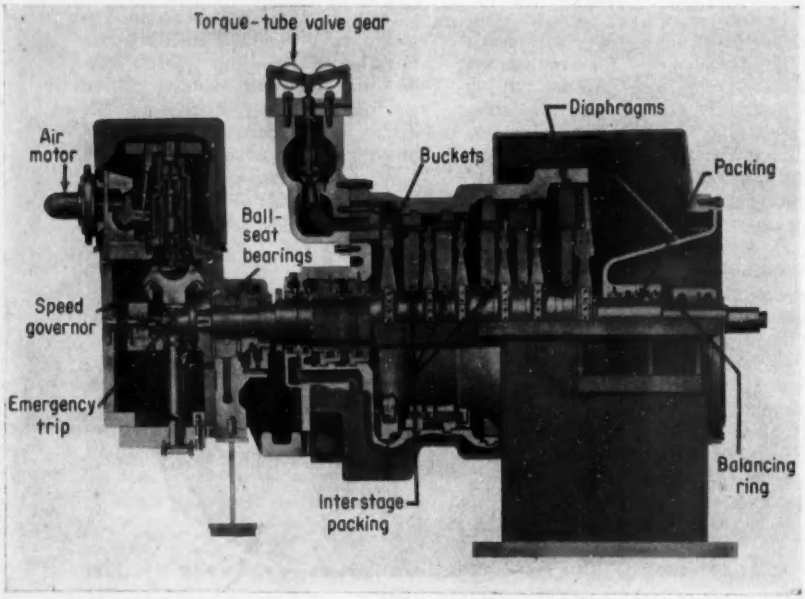


FIG. 1. Cross-sectional view of steam turbine and speed regulator.

bine by a change in load. This simulator represents the inertia offered in the turbine to changes both in load and in the rate of steam flow. Because both analogs are similar in concept, only the bowl pressure simulator will be described.

This component, Figure 4, is an analog of one of the steam bowls of the turbine and consists of an air chamber, whose volume can be set to any prescribed value by adjusting the water level. The inlet is a needle valve, which is controlled by the operation of the operating cylinder assembly. The outlet is an adjustable hand-operated angle valve.

By setting the two valves at previously calculated values, the pressure within the chamber can be maintained at equilibrium level, equivalent to the steam pressure within the bowl when the turbine is running at a constant speed under a constant load. If the air pressure within the speed unit is increased, simulating an increase in turbine speed, the flow area of the inlet needle valve to the bowl-pressure unit decreases. This decreases the pressure in the chamber, causing the air motor to act and changing the flow area of the needle valve in the speed simulator. Thus, the inlet valve represents the steam valve on a turbine, the outlet orifice represents the steam nozzle, the air pressure in the chamber simulates the steam bowl pressure, and the air volume corresponds with the volume of the bowl. The output from this chamber (the air-motor stroke) is proportional to steam torque as simulated by the needle valve area at the outlet of the speed simulator chamber. By adjusting the inlet needle valve area, the exit orifice area, bowl pressure simulator volume, and the equilibrium air pressure to the proper values obtained from prior mathematical analysis, the bowl pressure simulator can be made to perform exactly like a particular steam bowl on a turbine.

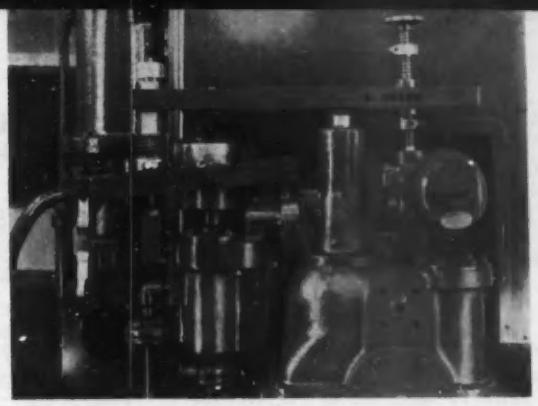


FIG. 2.
View of constant-speed governing system shows close-up of primary relay with fluid restoring mechanism.

Test objectives

In evaluating governor performance, the designers are especially interested in speed vs. time characteristics. Accordingly, the usual test routine consists of introducing load disturbances and measuring the time needed for the control to re-establish equilibrium. In beginning a typical test, the engineer might tighten the angle valve on the speed simulator (Figure 3) to represent an increase in turbine load. The resulting pressure drop within the speed unit causes the air motor to pull on the linkage system. This relieves a portion of the spring tension holding the flapper of the governor simulator against the air nozzle, indicating, in effect, a slowdown of the flyball governor. The pressure drop on the governor piston moves the linkages so that the tube of the pilot valve shifts upward.

This action of the pilot valve raises the oil pressure on the primary piston. The latter pushes up on its linkage system to shift the pilot valve bushing to its new position and also to widen the valve opening into the bowl-pressure unit. The air motor of the latter then tightens the exhaust valve in the speed simulator, restoring the pressure in the latter to its original value. Governor simulator, governor piston, and pilot-valve return to their previous positions, while the primary piston and operating cylinders remain at their new points of equilibrium.

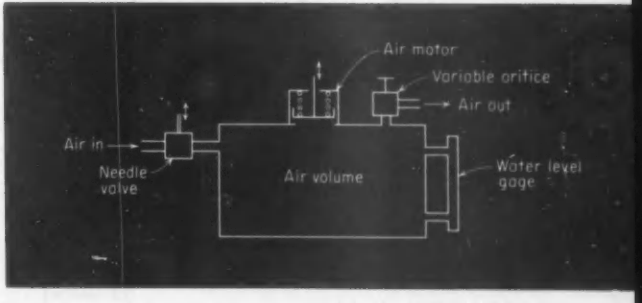


FIG. 4. Detail of bowl pressure simulator.

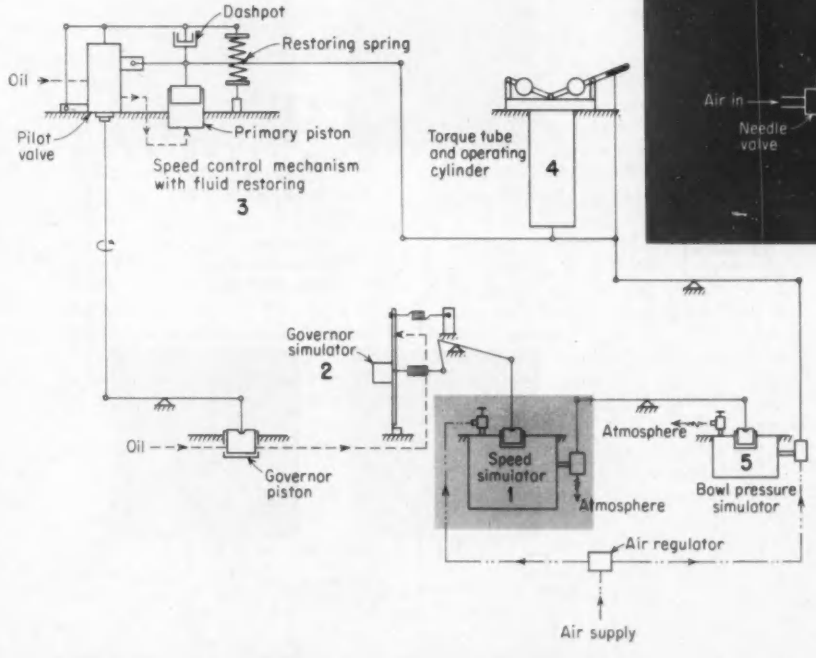


FIG. 3. Schematic of test system employing mechanical analog.

#6 Model Test Spots Spurious Programmer Circuits

H. LAW
The English Electric Co., Ltd.

Unexpected sneak circuits are likely to show up in a steel rolling mill programming unit when it gets large enough to comprise eight 16-bank, 50-position stepping switches. The big problem is how to find the unwanted circuits. Functional testing of the programmer running an $\frac{1}{4}$th scale model revealed unexpected interaction in the fault protection circuits and hidden leakage paths through the stepping switches.

In this case, model testing was done by chance. The scale model—operated from a normal full-size programming unit—was intended solely for sales demonstrations, to show automatic programming and control on all the functions of a hot reversing mill: main drive speed and direction, screwdown settings, manipulator operation and table roller speed and direction. But the model was completed ahead of the actual mill so the scale-unit received a functional checkout of the system first. Runs of the model under program control produced unexpected spurious results. Investigation revealed that parallel paths in the stepping switches were causing the trouble.

To understand how the spurious circuit developed, you have to review how the programmer works. It can be divided into three main sections (Figure 1): the program selector, the storage uniselectors, and the function generation units for each of the controlled variables. Input information—billet dimensions, final bloom size, and number of passes—feeds into each bank of the 16-level, 50-position program selector, from selector switches. The program selector is wired so that the switch wipers home to one unique position for any combination of inputs, selecting one of 50 built-in programs. This action of the program selector wiper energizes similar rows in all storage uniselectors. A separate, ratchet-operated, selector switch, triggered photo-electrically by the billet at the reversing points on the mill bed, sequentially scans each wiper of the storage uniselectors.

Figure 1 shows the system operating on program 11. On the seventh pass, row 3 on the first level of the screwdown function generator is energized. Homing to this position produces a resultant relay output of 0010011 to position the screwdown rollers. Reversal of the billet advances the pass selector switch to pass 8. This, in turn, energizes row 6 on the function selector. The new screwdown setting corresponds to the relay output 1011011.

In the initial design all wipers of the storage uniselectors corresponding to a given pass were paralleled; they were energized from a single bank pass-selector switch. The unforeseen sneak circuit that resulted is shown as a dotted line. It energized both rows 3 and 6 on the screwdown function unit when the pass selector moved from position 7 to 8.

Isolating the storage wipers by increasing the number of banks on the pass selector switch cured the fault which, with 750 connections between each uniselector, was unforeseeable in the design.

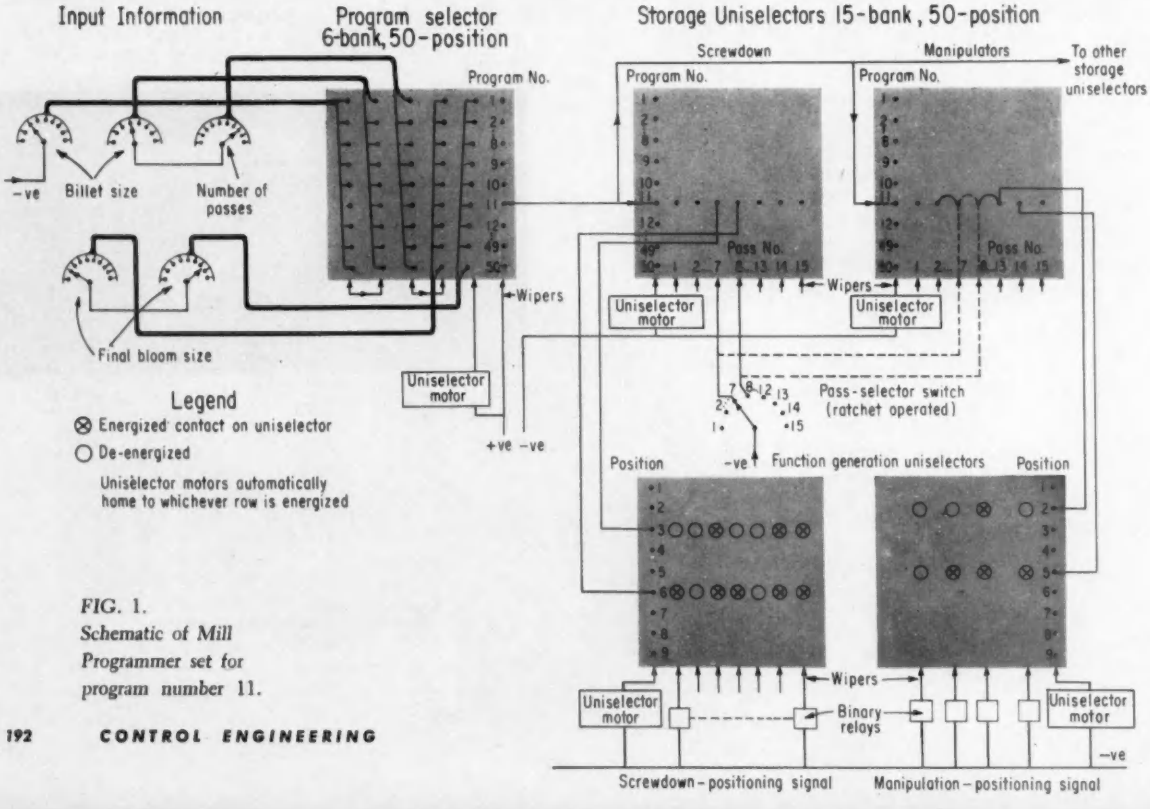


FIG. 1. Schematic of Mill Programmer set for program number 11.

FIG. 1. Operator adjusts Videotape recorder at White Sands Missile Range.

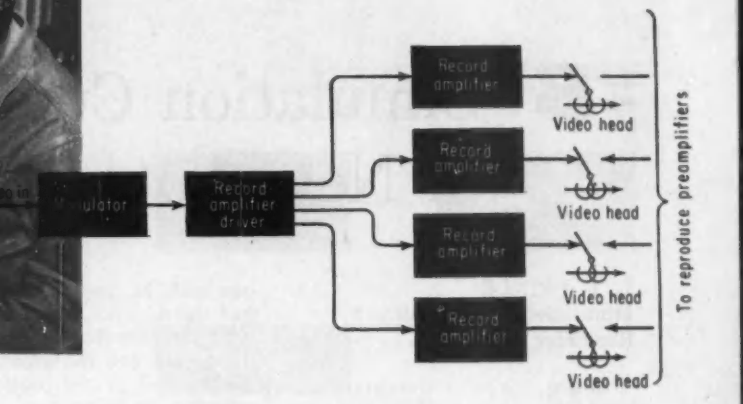


FIG. 2. Block diagram of input section of video recorder.

#7 Video Recorder Captures Missile Test Data

R. McCABE
Ampex Corp.

The same type of Videotape* recorder that is now "canning" a considerable number of television programs has been adopted at White Sands Missile Range in New Mexico to record radar signals. The signals originate in five missile-tracking radar stations strung out over a 4000-square mile firing range. The Videotape recorder supplants the motion-picture cameras previously employed to capture data from the radar screen. The recorder makes it possible to restudy various portions of the missile's trajectory without screening thousands of feet of film from optical systems. And the time delay encountered in developing the film is eliminated; the machine can play back immediately.

The machine was pressed into service by White Sands while it was still in prototype development. It is one of three pre-production models built by Ampex of its VR-1000 recorder and intended for use by the television industry. Its high frequency range and excellent response (± 3 db from 15 kc to 2.5 megacycles) make the video unit suitable for recording modified forms of radar signals, which are far above the frequency ranges of conventional magnetic-tape equipment.

Videotape recording of the radar signals is done in successive narrow, vertical bands on the tape by four small video heads. Sound can be captured longitudinally along one edge of the tape. The White Sands recorder has two audio channels. One channel records sounds of the blastoff. Another audio channel, added by Signal Corps engineers, is being used as a "cue" channel; it carries audio pulses that identify the locations of certain portions of the radar data recording selected for special study. Simultaneously with the video and audio recording, a control track is recorded longitudinally along the opposite edge of the tape. This control track provides for synchronization of tape and recording heads.

The system, which consists of electronics and a tape transport, fits into one double electronics rack and one console, Figure 1. The entire system requires less than 100 sq ft of floor space, including both recording and reproduction facilities. With 12½-in. reels, the machine provides up to 64 min of recording time.

Figure 2 is a block diagram of the record end of the system. The converted radar signal modulates a high-frequency carrier. This frequency-modulated signal is amplified and then impressed on the video heads. A modulator circuit is in operation during the record mode, while a demodulator circuit is in operation during the reproduce mode. This modulator-demodulator circuitry serves the dual purpose of producing the frequency modulated signal during the recording process and of recovering the original video signal by demodulation during the reproduction process.

The outstanding single feature of the equipment design is a special helical method of recording, which permits the video information to be packed on the tape in tight, vertical tracks. Containing frequency components in a range that approaches direct current at the low end and extends to over 4 megacycles at the upper end, video recording requires more tape area than does the audio spectrum. For example, a conventional audio recorder, operating at a tape speed of 7½ ips, records a 15-kc signal at a rate of 2 kc per inch of tape, thus the wavelength of that signal as it appears on the tape is ½ mm. To record a 4-megacycle signal so that its wavelength on the tape would be ½ mm (assuming the use of the same type head) would require a tape speed of 2,000 ips.

Obviously, to provide an hour of Videotape recording with this method would require a reel of gigantic proportions. In helical recording, the 2-in.-wide magnetic tape, moving at only 15 ips, curves past a rotating disc with four equally spaced magnetic heads. Information is packed rapidly onto the magnetic tape because each head, in turn, records successive, narrow, vertical bands of video information. Speed of the head assembly is 14,000 rpm. In this way, a head-to-tape velocity approaching 1,500 ips is attained.

* Trade mark of Ampex Corp.

#8 Simulation Cuts Flight Tests of New Autopilot

L. T. PRINCE
Minneapolis-Honeywell Regulator Co.

Analog computer simulation has played a significant role in the conceptual development, design, and flight testing of the Honeywell adaptive flight control system, a new autopilot currently being flight-tested in an F-101A airplane.

A major objective in the development of the adaptive autopilot was to achieve higher performance and greater flexibility in automatic flight control without significantly increasing autopilot complexity. Analog simulations were used to evaluate various basic concepts, the more promising of which added nonlinear devices to the system, and an "optimum" configuration based on system requirements was arrived at. Simulation proved extremely useful because a large amount of data could be obtained quickly in a form that could be readily interpreted by the engineer. The decision to conduct a feasibility flight test of the most promising concept was based primarily on the success of simulator studies. The first flight test was of a single-axis controller and was conducted in an F-94C. The results were in excellent agreement with the previous computer studies, so it was decided to design, fabricate, and flight test a complete three-axis adaptive flight control system.

During design of the three-axis system, analog computer simulation was used again, this time to evaluate changes proposed in the basic concept. One of the recommendations was to replace a dithered electronic relay in the system with a dithered relay whose bi-stable output voltage could be controlled by an external signal. This new electronic device, the gain changer, adjusts autopilot gains and the maximum rates commanded of the control surface actuators as a function of certain aerodynamic characteristics of the airplane. Figure 1 is typical of the gain changer characteristics.

A typical computer simulation diagram for the adaptive autopilot in the pitch axis only is shown in Figure 2. The airplane, gyro, and airplane control system were also simulated during the earlier stages of development, and extensive studies were made to investigate the sensitivity of the complete system to changing airplane dynamic characteristics and variations in autopilot component characteristics. Preliminary design specifications were based on the results of the computer study.

Simulation at the breadboard stage

A unique feature of analog computer simulation is the ability to couple breadboard autopilot components directly to the computer in order to evaluate functional design of hardware before flightworthy equipment is fabricated. This technique can considerably reduce the time required to arrive at a satisfactory design of the autopilot components, and was profitably used during this system development. The modified simulation for this phase is diagrammed in Figure 3.

Even when flightworthy autopilot equipment was ready for installation in the airplane, the computer was used to expedite and fulfill initial ground checkout of the system. During this final phase of the development program, the computer was "wheeled" out to the airplane and used to simulate only the flight dynamics of the airplane. The flightworthy autopilot equipment was used with the actual autopilot servos and power actuators of the airplane in a series of simulated flights. At this stage the simulator diagram looked like Figure 4. The computer

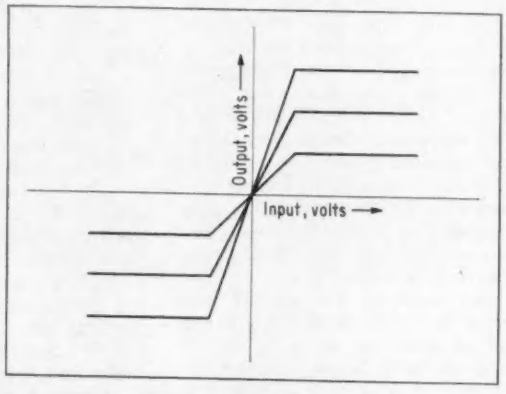


FIG. 1. Gain and saturation limits in "gain changer" depend on flight conditions.

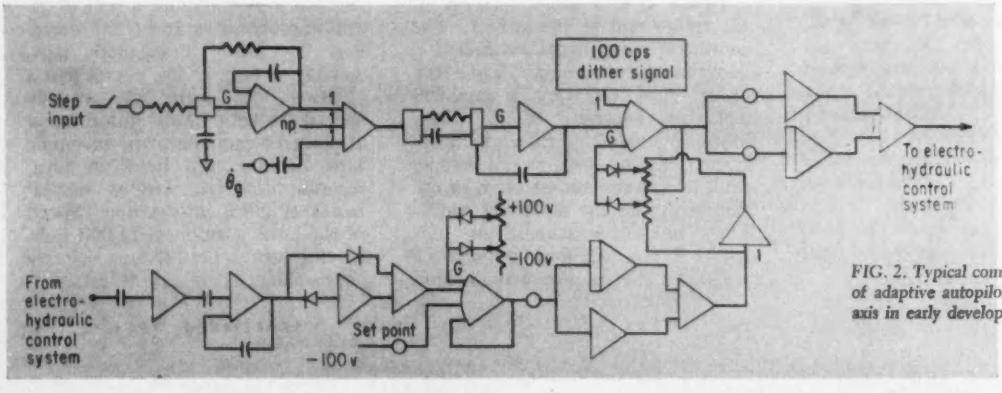


FIG. 2. Typical computer simulation of adaptive autopilot pitch axis in early development stage.

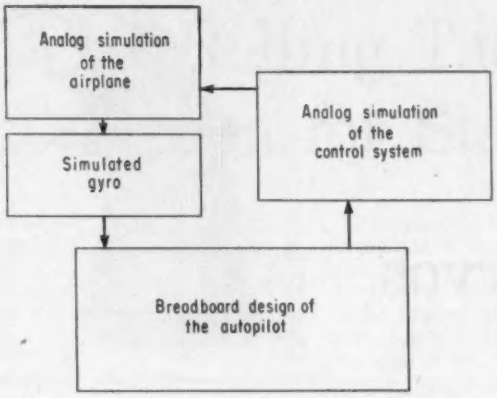

Analog simulation of the airplane
Simulated gyro
Analog simulation of the control system
Breadboard design of the autopilot

FIG. 3. Simulation setup to evaluate autopilot at breadboard stage.

FIG. 4. Simulation setup during final ground check-out of the adaptive autopilot. Only airplane flight characteristics are simulated.

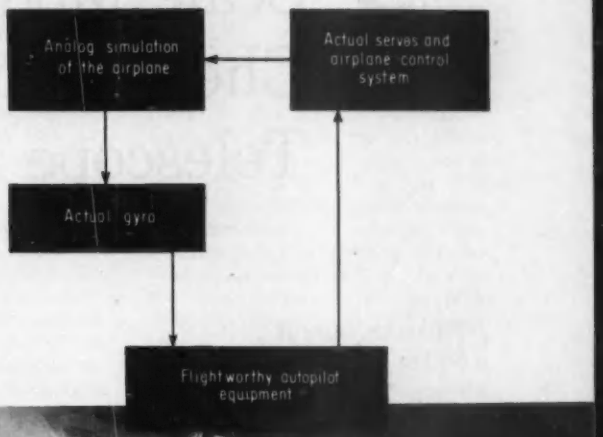

Analog simulation of the airplane
Actual servos and airplane control system
Actual gyro
Flightworthy autopilot equipment

FIG. 5. Analog computer tied in to activated electrohydraulic control system on F-101A and flightworthy version of adaptive autopilot (installed in airplane, but not visible). In this final ground check-out, computer simulates airplane flight characteristics only; all other dynamics result from use of actual equipment.

signal representing the angular motion of the airplane was used to rotate a "rate table" in the same manner as the airplane would actually maneuver, and the real gyros were mounted on the rate table. Thus, the most realistic evaluation of the system obtainable without actually flying was made.

Figure 5 shows the computer actually connected to the control system of an F-101A during the final checkout stage of the development. An airborne recorder is on the table in the left foreground, but the autopilot is not visible.

The performance of the three-axis adaptive flight control was evaluated at various speeds and altitudes at which the airplane was to be flown by introducing into the system simulated pilot commands from the airplane control stick and gusty air disturbances from the computer. As a result of the ground checkout, several minor modifications were made in the autopilot to minimize the effects of noise and control system backlash. This program allowed system performance to be further improved before the first flight was made and was instrumental in eliminating the need for any autopilot "shakedown" flights.

During the actual developmental flight testing, only minor adjustments in the system were required as a result of pilot comments and the evaluation of flight test records. For example, the values of certain components were changed to make the flight smoother, especially in turbulent air. Correspondence between ground tests of the system and actual flight tests proved to be excellent. This resulted in very few actual flights needed to optimize the system and greater confidence in the results of simulator studies. Because of the high cost of flight testing today's aircraft and missiles, reduction in the number of flights required is highly desirable. Analog computer simulation provides a proven way.

#9 Scale Model Checks Out Telescope Servos

FIG. 1. Scale model of radio telescope used in tests.

THOMAS DOSCH
Reeves Instrument Co.

The model shown in Figure 1 is a scaled-down replica of an advanced-design radio telescope now being built for tracking space vehicles. The actual telescope is huge in size, measuring about 20 ft from the bottom of the pedestal to the top of the "dish" or antenna. The antenna can be moved about three axes; the rotating part of the structure weighs over four tons. A most significant part of the telescope design is that it is one of the first applications of the MIT-developed direct-drive, gearless torque motors. The use of the new type of actuator eliminates the backlash problem completely and makes possible the extremely high-precision servos required for long-range tracking.

The dc servo motors are controlled through a Ward Leonard drive system, Figure 2. To achieve high torque without gear reduction, the motor diameters are large; for example, the azimuth motor, which is built as an integral part of the pedestal has a 4-ft OD.

The novelty of the servo drives made testing an essential stage in the design process. The problem was that the servo electronics had to be completed before either the pedestal or the motors were available for test. Fortunately, it was feasible to check out the actual electronic subsystems by simulating the final servo with a scaled-down motor and load. The table compares the characteristics of the full-size motor and load with those of the model.

To prove the validity of the tests, the equations relating output angle θ_o to generator voltage V will be derived. If the output angle $\frac{\theta_{o2}}{N}$ for the model can be made equal to the output angle θ_{o1} of the actual unit at all frequencies, then the model performs in the same manner as the actual unit. For either unit:

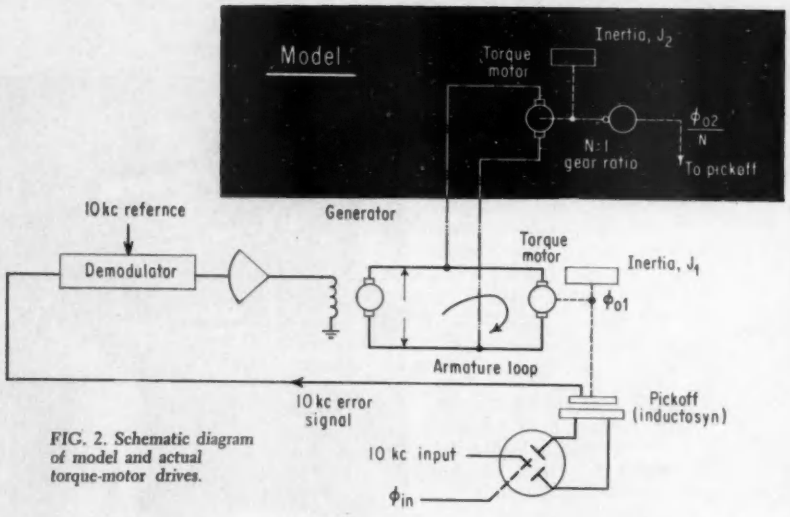


FIG. 2. Schematic diagram of model and actual torque-motor drives.

$$V = K_e s\theta + I(R + sL) \quad (1)$$

$$T = K_T I = s^2 J \theta \quad (2)$$

where: K_T = torque constant of motor
K_e = back-emf constant of motor
R = resistance of armature loop
L = inductance of armature loop

From Equations 1 and 2, and letting $\omega_e = R/L$ and $\omega_c = K_e K_T/RJ$:

$$V = sK_e\left[\frac{s}{\omega_c} + 1 + \frac{s^2}{\omega_c\omega_e}\right]\theta \quad (3)$$

$$V = IR\left[1 + \frac{\omega}{s_e} + \frac{\omega_e}{s}\right] \quad (4)$$

Equation 3 shows that the model performs as does the actual unit if its corner frequencies ω_e and ω_c are identical with those of the full-scale unit, and if its output angle θ is taken not directly at the motor but after gear step down of N:1, where:

$$N = \frac{K_e \text{ of actual motor}}{K_e \text{ of model motor}}$$

Consistent with this analysis, the tests were conducted with a scaled-down motor having armature resistance and inductance less than those of the full-size motor, and having a sufficiently high mechanical corner frequency ω_c. Resistance and inductance were in series with the model to bring the total values of these parameters up to those of the actual motor. The inertia load was chosen so as to make the ω_e of the model equal to that of the actual telescope. The model motor was geared to the pick-off through an N:1 gear ratio and provision made for power limiting to prevent thermal damage.

Comparison of Characteristics

	Actual	Model
Torque constant (ft-lb/amp)...	100	0.27
EMF constant (volt-sec/rad)...	136	0.37
Inertia (slug-ft²).....	700	0.01

#10 Rolling Table Simulates Sea for Stabilizer

J. BELL
Muirhead and Co., Ltd.

Closed loop testing is required to check the design of ship stabilizer systems. But the cost and unpredictability of actual sea conditions rule out full-scale vessel tests for development purposes. And model tests in marine tanks are tricky to instrument; the results are often difficult to interpret. One ship builder has solved the problem with a rolling table whose periodicity and damping can be adjusted to the ship under study. (Periodicity variations range from 27 seconds for the Queen Mary to three seconds for a small yacht).

When the stabilizer control is working, the ship's motion is determined by the difference between the rolling forces imposed on the ship by sea conditions and cancelling forces generated by the stabilizing equipment. This small irregular motion, detected by gyroscopic sensors, generates the stabilizing signals.

To simulate closed loop stabilization, the table is rolled by an external force that represents the sea conditions against which the stabilizer must deliver counteracting torque. Two servo-operated sliding weights produce rolling and stabilizing torque on the table (Figure 1).

Simulated sea functions are generated by a variable speed motorized cam follower. The cam consists of a 12-inch diameter wheel divided into sixteen sections. A piece of thin card or metal that has been profiled to correspond to the required sea condition is inserted into each section. By varying the sequence of the sections, testers can simulate any wave motion from calm water followed by a single steep fronted wave to seas of sinusoidal character and varying amplitude. Waves with frequencies different from or corresponding to the ship's periodicity can also be simulated. To provide an electrical output proportional to the sea conditions, a lever mechanism follows the cam contours and operates a synchro transmitter.

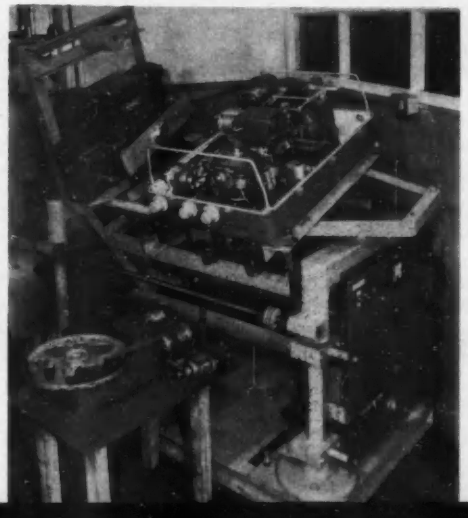
The table (Figure 2) is a metal frame on which is mounted the full-size gyroscopic sensing unit and the first stage hydraulic relay unit. Also mounted on the table is additional hydraulic equipment whose response is adjusted to correspond with the response of the full-scale operating units in the ship. After static-balancing the table, testers adjust the pendulous loading to set up a periodicity equivalent to that of the ship under investigation. Rolling decrement of the table is made equal to that of the ship by altering the point of two vanes mounted on the underside of the table and their immersion into a water tank. Plane free bearings at either end of the table reduce the static friction below that required for minimum damping.

The rolling effect of the sea forces is simulated by a servo-driven weight that applies a torque about the table's operating center. The sea-force signal from the synchro transmitter drives a servomotor to move, through a reduction gear, an adjustable ½- to 5-lb weight along a line at right angles to the rolling axis. The weight moves in the horizontal plane of the rolling axis so that its acceleration from one position to another imposes no additional rolling torque on the table. With the normal table damping decrement of half amplitude in two periods, the sinusoidal movement of the weight gives a roll amplitude of almost six times the static deflection caused by the maximum moment of the weight.

Detecting the rolling of the table, the gyroscopic sensing unit generates electrical outputs proportional to roll angle, roll velocity, and acceleration. Fed to the hydraulic relay unit, the resultant positioning signal normally is amplified hydraulically to power levels up to 100 hp, necessary to actuate the fin positioners. On the analog table, however, the positioning signal moves a second corresponding weight in the same plane. But the movement is in the opposite sense to the sea disturbance weight. The opposite sense moment cancels out a large proportion of the rolling motion imposed on the table by the sea function.

When the stabilizing equipment is switched off, rolling period and amplitudes of the table caused by the movement of the sea disturbance weight are checked. Switching in the stabilizer causes the stabilizing weight to counteract the free rolling of the table.

FIG. 2. Rolling table. Hydraulic relay unit is at right; gyroscopic sensing unit at left. Sea-force generator, with 16-sector cam, is in the foreground.



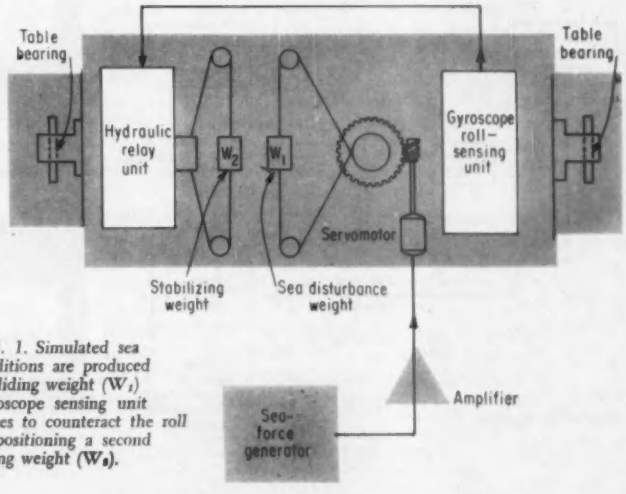


FIG. 1. Simulated sea conditions are produced by sliding weight (W_1) Gyroscope sensing unit moves to counteract the roll by positioning a second sliding weight (W_2).

#11 Wire Telemetry at Cape Canaveral

R. P. GRAEBER
RCA Service Co.

D. N. DEDERER
Control Engineering

At the Atlantic Missile Range, data are transmitted by wire from permanent and semi-permanent tracking installations to data processing facilities and the central control room. Wire telemetry (see page 171) was selected to obtain simplicity and reliability for transmission over distances which range from 70 feet to the 1,100 miles spanned by the submarine cable connecting Cape Canaveral with Puerto Rico and the in-between down-range stations.

Among the wire techniques used are shaped serial tone bursts, teletype analog transmission (voltage level), parallel transmission on 36 lines by dc shift, and parallel transmission by pulses. Each wire telemetry technique chosen at the Cape represents a compromise for solution of a specific set of requirements. For some functions, such as range safety, the value of data decays rapidly with time—data more than a few seconds old are worthless. In other cases, allowable data gathering times are on the order of minutes or even days.

The first important instrument system to be linked by wire telemetry was the Present Position and Target Acquisition System (Figure 1). Still an important part of the range, it tracks a vehicle with radar, reporting the missile's position back to a display at central control and supplying acquisition data to other radar and optical instruments, which can then follow flight. To put a new high precision radar on target at a down range station, for example, requires precise data, fractions of a second after they have been acquired.

Here is how it works right after a missile leaves the launching pad. As a radar at Cape Canaveral follows the missile, range, azimuth, and elevation data are picked off precision analog potentiometers on the radar itself, translated to X-Y-*H* cartesian coordinates in an analog computer close to the instrument. Next, the data are digitized and transmitted as shaped tone bursts (whose principal advantage is reliability), 480 pulses per sec. The signal is carried to optical trackers nearby and to the central control room by land line, to down-range radar installations over the coaxial submarine cable. At its instrument destinations, the data are restored to analog form, passed through a second analog computer which translates them into acquisition data to put the instrument on target. At the central control room, the data pass through a second analog computer to be put in a form which can be displayed on plotting boards.

Experience has shown that a shaped tone burst of three cycles can be transmitted and recovered reliably. Because of this size, the *minimum* modulation frequency is set at 6 kc; actually 6.2 kc is used. When a bit of data enters the modulators, it passes through a pulse stretcher, then opens a gate on the 6 kc signal which is filtered for proper wave shape to enter the lines.

Another system, which depends on transmission of data over wire pairs, is the impact predictor (CtE, Feb. '59, p. 23). It plays a key role in range safety, telling the range officer where a missile will fall at any instant if its fuel is cut off. There are two data transmission problems involved. First, data from radars and the AZUSA system (a high accuracy tracking system using continuous waves) have to be sent to an IBM 709 computer where impact points are computed. Then the results have to be transmitted to the central control room where the range safety officer has access to them.

Data from the AZUSA system are carried by 36 parallel coaxial cables into the computer input—about 70 feet. Because the radars are located approximately 20 and 165 miles from

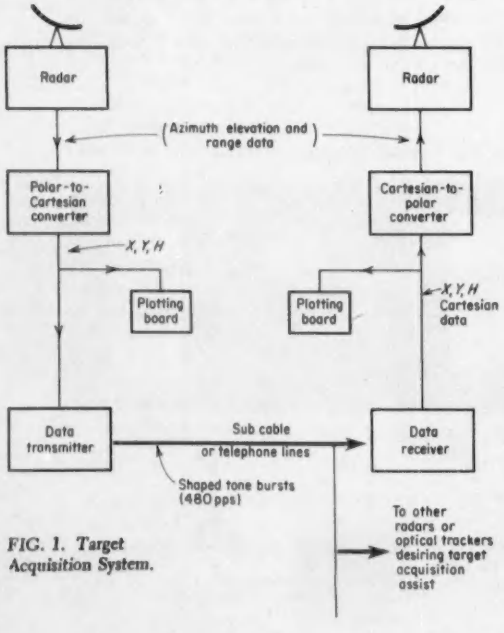
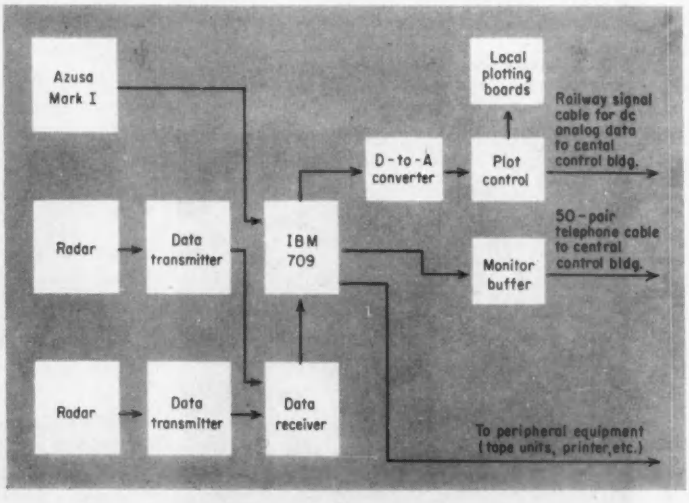


FIG. 1. Target Acquisition System.

FIG. 2. Impact Predictor System.



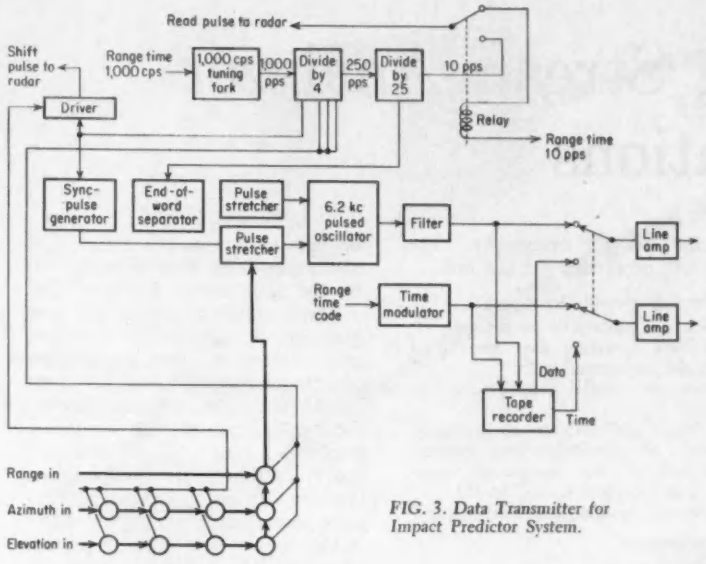


FIG. 3. Data Transmitter for Impact Predictor System.

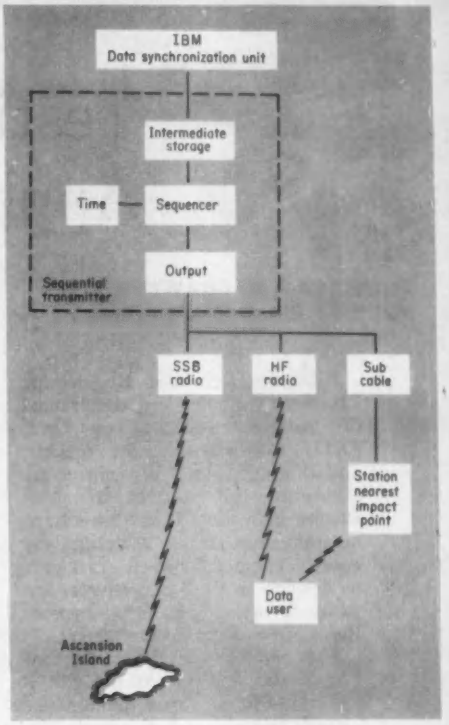


FIG. 4. Teletype Transmission of Target Acquisition Data.

the computer sites, a more sophisticated transmission system is needed.

In this application, the data are digitized right on the radars. Azimuth, elevation shafts, and the range potentiometer servo shaft each drives two encoders, a fine optical encoder and a coarse mechanical encoder. A single positive pulse will strobe all six encoders simultaneously, sending the information contained in the encoders to corresponding shift registers. Data stored in the registers are then shifted out in serial form and moved to the data transmitter on three separate lines.

The data transmitter (Figure 3) actually performs two functions: interrogation of the radar shaft encoders and transmission of this data via land line and/or submarine cable to the receiver at Cape Canaveral. Read pulses are sent by the transmitter at the rate of 10 pulses per sec, each pulse causing all the radar encoders to read simultaneously. In addition, the transmitter sends out shift pulses at the rate of 250 per sec to cause one bit of elevation, azimuth, and range data to be shifted out simultaneously on three parallel lines.

The three parallel bits enter three cores in the data transmitter, and are shifted by a 1,000 pps pulse into the pulse stretching network. Then they pass into the modulator circuit. Gates are opened by the stretched pulses to allow a burst of 6.2 kc to pass into a shaping network, and then onto the transmission lines. In the data receiver, the time bursts are first detected, then stored in a core shift register. They are read into the IBM 709 computer as three separate sequential 36-bit words.

After computation, the results are converted to a dc analog form and transmitted by railway signal cable to an analog computing and display network in central control. The railway cable—merely well shielded, low resistance cable—allows the precision analog voltages to be transmitted with minimum distortion.

When the Vanguard satellite was being launched, another link was added. The Impact Predictor System supplied data to back up the firing of the third stage rocket, which is normally ignited automatically from internal devices. At burnout of Vanguard's second stage engine, the computer detects that the impact point has stopped moving, and it initiates a new routine. Taking data from the tracking radars, the machine computes third stage apogee (the point of highest flight). As a backup, the computation is repeated using data telemetered from airborne integrating accelerometers.

When the impact predictor is used to compute third stage apogee, data for this purpose exit from the IBM 709 as 12 decimal digits in binary-coded-decimal format. The BCD signals drive relay matrices which change the code to seven discrete voltage signals required to actuate digital indicator lights. These seven voltages per digit are transmitted in parallel over telephone lines to the Naval Research Console in the central control room, one mile away.

Another interesting real time data processing and transmission technique is called "In Flight" operation. This involves sending acquisition data to down-range missile tracking ships and/or island sites which are not served by submarine cable. The technique: teletype via telephone lines, then high-powered, high-frequency radio to the ship or island site. For Atlantic Missile Range operation, a unique black box has been built to mate electrically the computer addresses and the teletype format transmission (Figure 4).

During a nose cone recovery operation, for example, there is sufficient time between the calculation of the impact point and the arrival of the missile at the point, for data to be teletyped to tracking crews on the ship, where they can set the data manually into analog target acquisition computers, which adjust radars.

After point of impact is calculated in the IBM 709, the computer codes the result in Baudot code, transfers it to a "block" of the core memory. The data block is then "connected" to a data synchronizer channel, sequenced into the "black box" which transforms it to serial teletype format and then transports it via telephone line to a high power radio transmitting station. From here the signal is radioed to the ship.

#12 Testing Stream-Analyzer Applications

HARRY M. CRAWFORD
Esso Research & Engineering Co.

Esso Research and Engineering Co. has developed and constructed the Analyzer Systems Test Unit, ASTU, to systematically, quickly, and thoroughly explore refinery applications for continuous plant stream analyzers. With the advent of numerous stream analyzers, the control engineer's job is no longer to develop or find an analyzer, but to apply in an economical manner those instruments on the market.

The photograph shows the inside of the ASTU. At the left is a Perkin-Elmer vapor fractometer (chromatograph) and its sample system. Not shown, but since installed, are recorders for analyzers to measure hydrogen, initial and final boiling point, vapor pressure, moisture, and trace oxygen. Pertinent temperatures, pressures, and flows will also be monitored during economic studies. The utilities and signal inputs and outputs are brought out through portholes. All electrical equipment meets the National Electrical Code for Class I, Group D, Div. II areas. An explosivity meter samples the ASTU environment.

The main purpose of the ASTU is to test the application of analyzers, not the analyzer equipment. The tests will be carried out like this:

At the Engineering Department

1. Select a process to be studied.
2. Review operating data from pilot plants and commercial units.
3. List all possible applications for analyzers.
4. Obtain and calibrate all analyzers. Fabricate all sample-handling systems.
5. Mount all test equipment, spare parts, and recorders in the ASTU.
6. Ship all equipment to the refinery.

At the Refinery

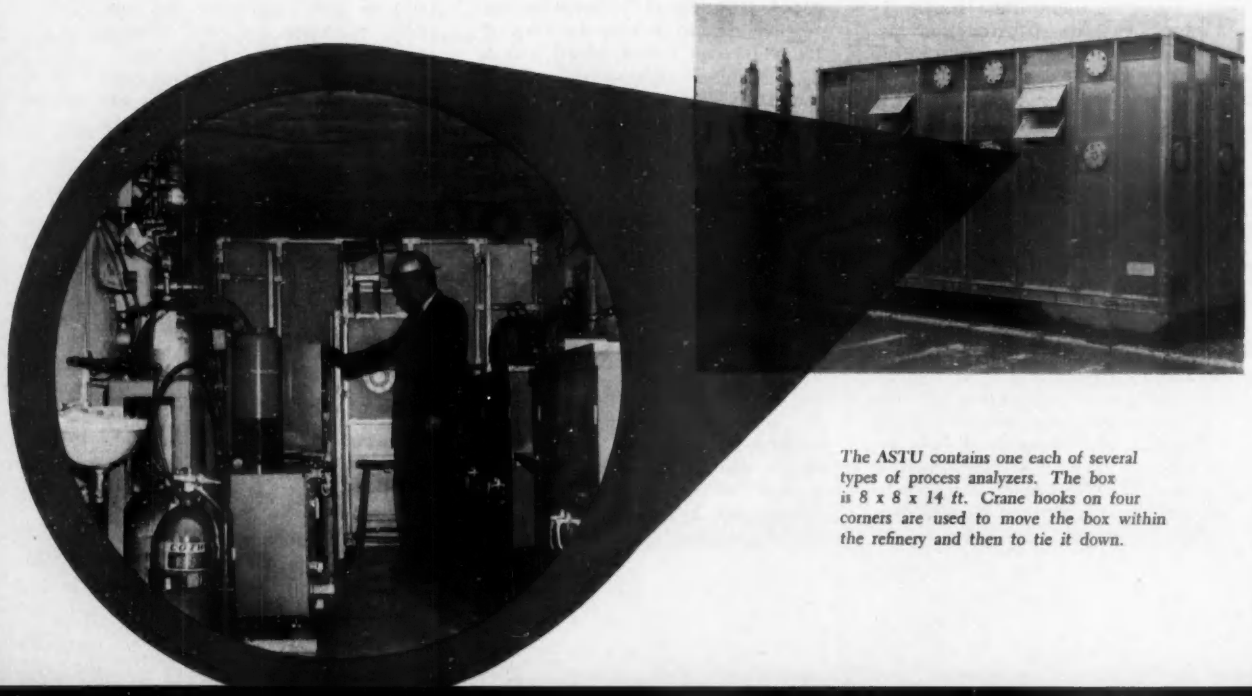
7. Connect analyzers to process.
8. Establish where analyzers should be permanently installed.
9. Document economics for (8).
10. Train refinery personnel on successfully applied equipment.
11. Write reports so that affiliated refineries with similar process units can duplicate successful installations.
12. Ship ASTU (and analyzers) back to Engineering and repeat (1) through (11) for the next process. For step (4) recalibrate analyzers for new applications.

The petroleum industry has two unique factors in its favor: there are only a few basic processes and a few basic analysis methods. Over 90 percent of all refining capacity is handled by distillation, reforming, cracking, light-ends conversion, and light-ends recovery processes. Thus, if a thorough study of one type of process is conducted, the results can be applied to similar units. Catalytic reforming—Powerforming—will be the first process to be studied.

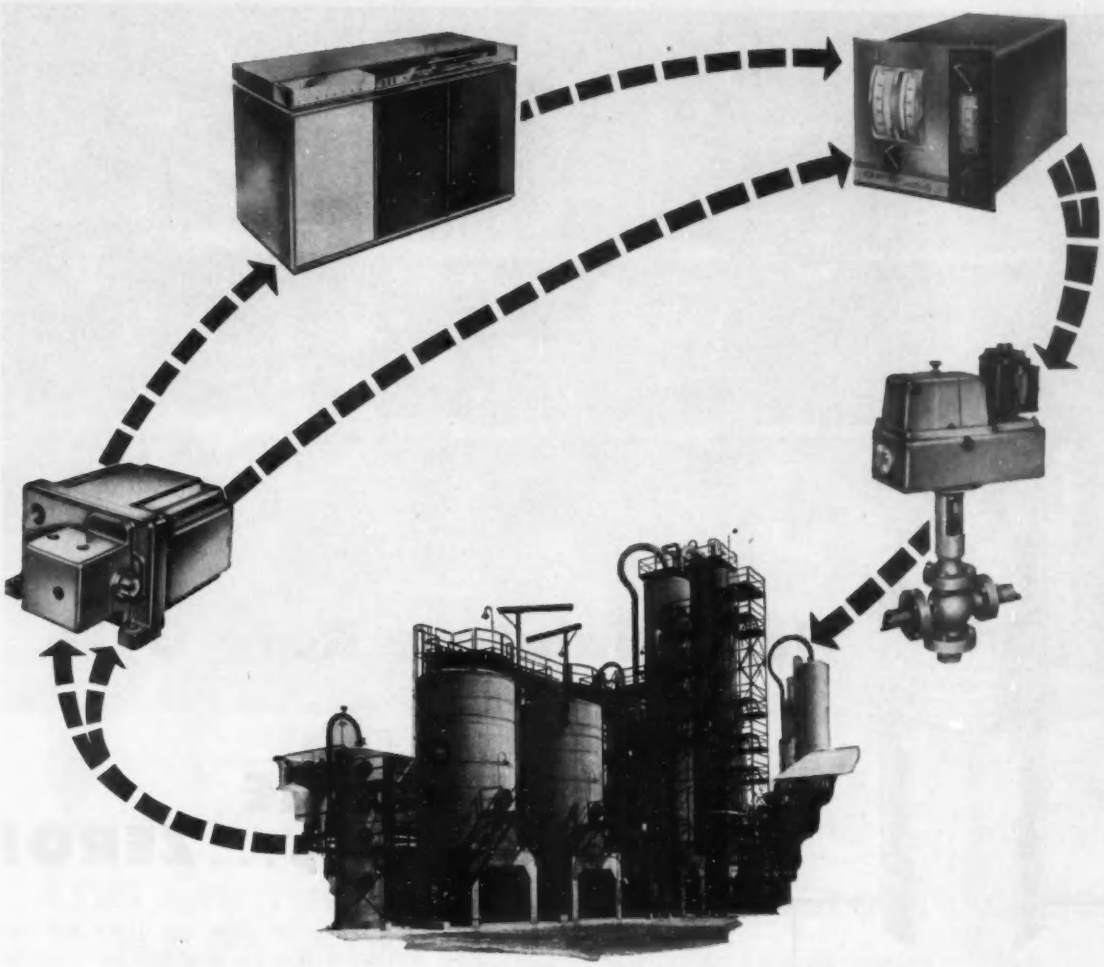
Many light hydrocarbon and inert gases can be analyzed by chromatographic methods. Thus, by installing one chromatographic analyzer in the ASTU, the control engineer can test the application of the chromatographs to a variety of problems on a variety of processes. Likewise, one viscosity recorder can be used to explore several applications.

The biggest and most important job for the ASTU is to document the economics of successful analyzer applications. To do this, all analyzer outputs will be recorded in the ASTU such that one or several days of analyzer data can be documented *before* plant operating personnel are given the opportunity to use the analyzer to take corrective action. Documenting the *after* data is likewise accomplished by taking several days of records after the plant operators and ASTU technical personnel have established how best to use the analyzer data for corrective action. In this way, it is hoped to prove (by actual chart records) the economics of analyzer applications.

The ASTU will also be used to train instrument maintenance men and to reduce the delay encountered when installing analyzers.



The ASTU contains one each of several types of process analyzers. The box is 8 x 8 x 14 ft. Crane hooks on four corners are used to move the box within the refinery and then to tie it down.



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Type M-100
shown actual size

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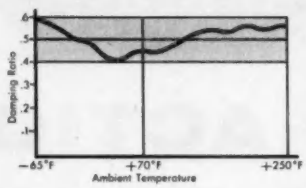
after motor run-up . . . ZERO!



When the chips are down and immediate action is a must, the new Honeywell Miniature Rate Gyros, Type M-100, are always ready. The typical damping of 0.6 at −65°F is obtained *without benefit of heat* from the spin motor, and is held virtually constant up to a temperature of +250°F. The gyro spin motor, requiring only 15 seconds run-up time, will operate on one (split), two, or three phase power, and is isolated from ground.

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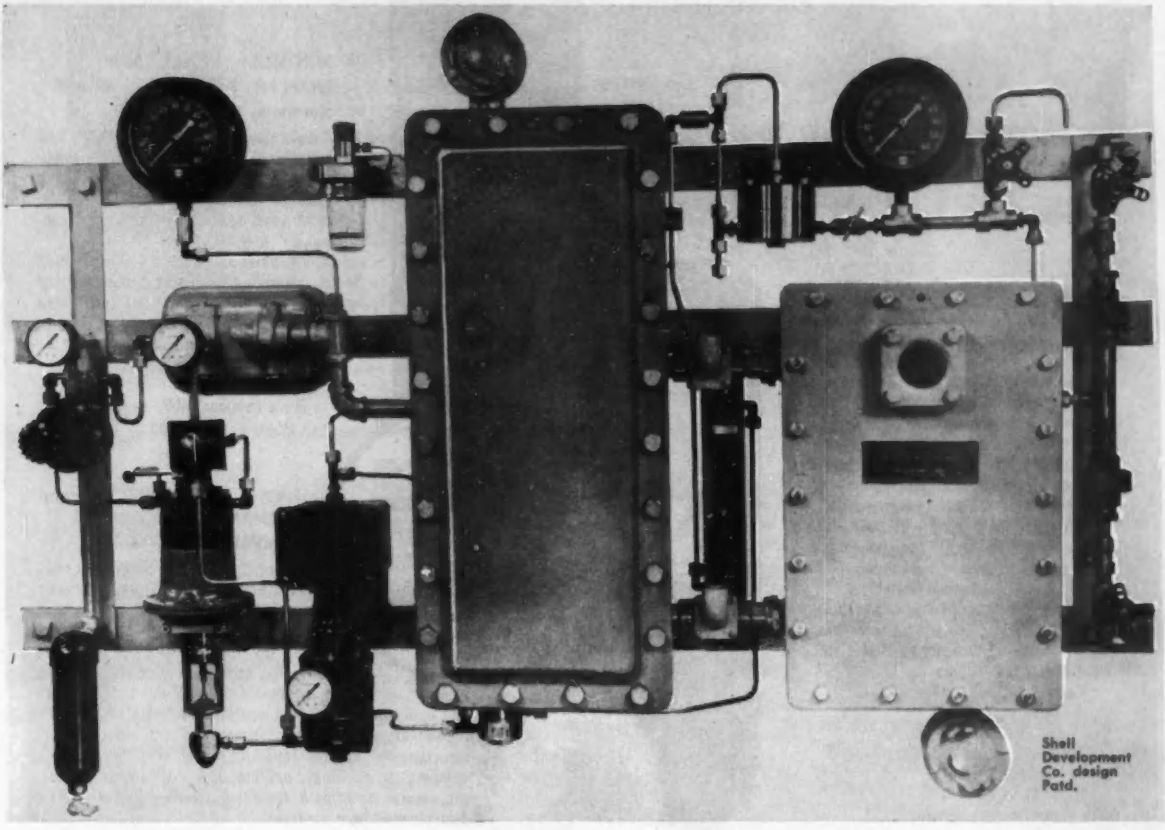

This Continuous Vapor-Pressure Recorder PAYS OUT in one to three months

It continuously samples and records the vapor pressure of gasoline or liquefied gases in a flowing stream.

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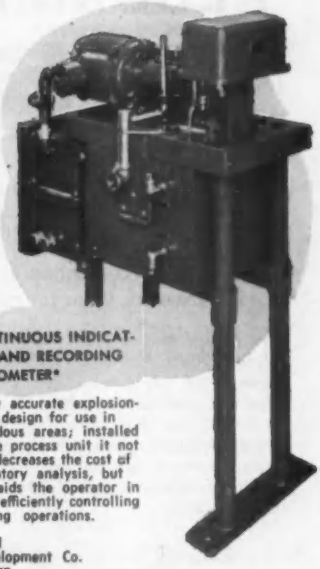

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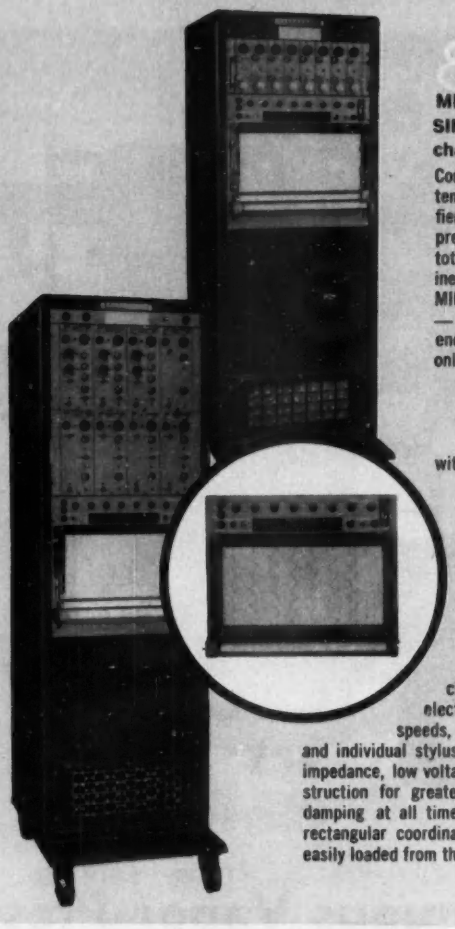

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MAXIMUM PERFORMANCE VERSATILITY — 6 or 8 channels, DC to 150 cps

Linearity 0.5%, 3 db down at 150 cps (10 div peak-to-peak amplitude). Improved current feedback power amplifiers, negligible drift. Total panel space only 38½". Efficient ducted air system assures constant, adequate cooling of all circuits for reliable operation.

VERSATILE "350" SERIES PREAMPS — compact (10½" high) interchangeable units with highly developed circuitry; for use in "350" systems, or individually (see "450" unit Amplifiers) with its own power supply to drive optical recorders, tape recorders, 'scopes, meters, etc. Available types include

- Carrier
- DC Coupling
- Phase Sensitive Demodulator
- True Differential Wide Band DC (4 models)
- Basic Chopper

with others in development

850

MINIMUM PANEL SPACE, SIMPLER PREAMPS — 6 or 8 channels, DC to 150 cps

Comparable performance to "350" System; uses same Recorder-Power Amplifier unit. Modules of up to 8 plug-in preamps occupy 7" of panel space; total panel space only 28" (max.); cabinet 60" high.

MINIATURIZED "850" SERIES PREAMPS — simplified, economical plug-in front ends for "850" systems; panel area only 2$\frac{1}{16}$" x 7". Types include

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- Basic Chopper (MOPA required)

with others in development

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6- or 8-channel recorder with transistorized, current feedback Power Amplifiers and voltage regulated power supply. Sensitivity 0.1 volt/chart div; panel space 17½"; nine electrically controlled pushbutton chart speeds, or remote control; automatic over-all and individual stylus heat control; time-code marker; low impedance, low voltage galvanometers with enclosed construction for greater reliability; true velocity feedback damping at all times, limiting ahead of output. Inkless, rectangular coordinate recording on Permapaper charts, easily loaded from the front.

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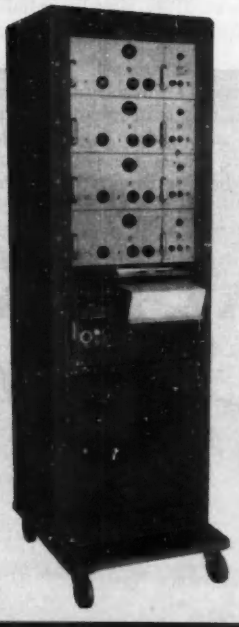
- DC Coupling
- Log-Audio
- Low Level
- Stabilized DC
- AC Wattmeter
- RMS Volt/Ammeter
- 400 Cycle Frequency Deviation
- Frequency Meter
- Triplexer 3-channel electronic switch



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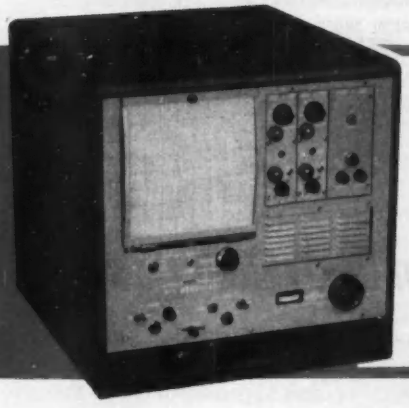

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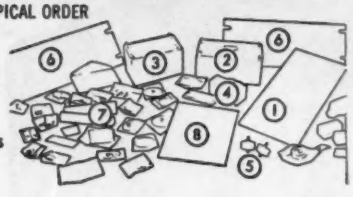

All of the components for a Control System DELIVERED IN 3 DAYS!

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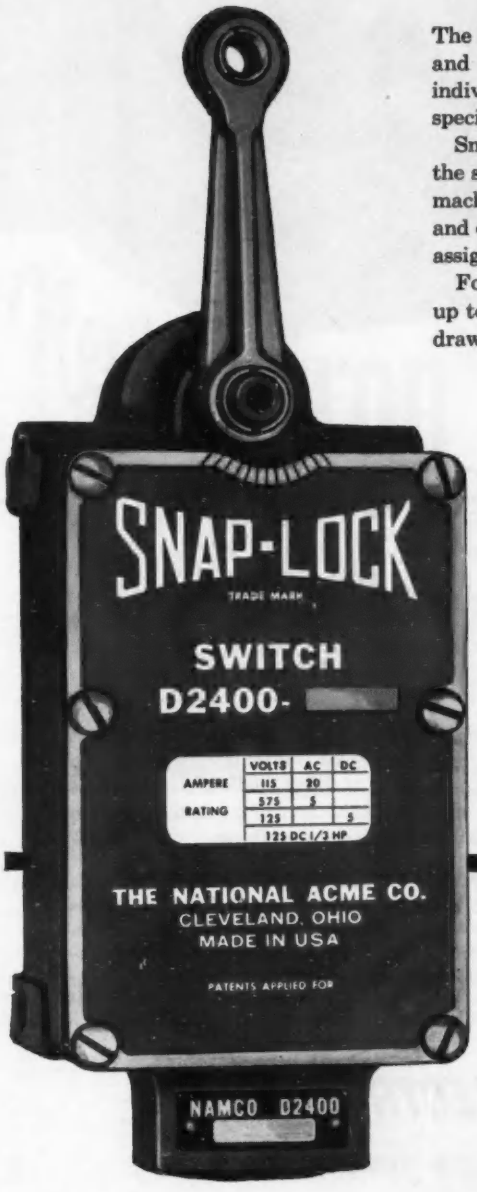

The D-2400 series Snap-Lock Limit Switches with two normally open and two normally closed contacts permit making or breaking two individual circuits simultaneously. Mounting problems are simplified, special linkages eliminated and costs kept to a minimum.

Snap-Lock Limit Switches were originated by National Acme to meet the severe mechanical and electrical conditions imposed by all types of machine tools. The outstanding simplicity and ruggedness of these water and oil tight switches make them adaptable to the toughest heavy-duty assignments.

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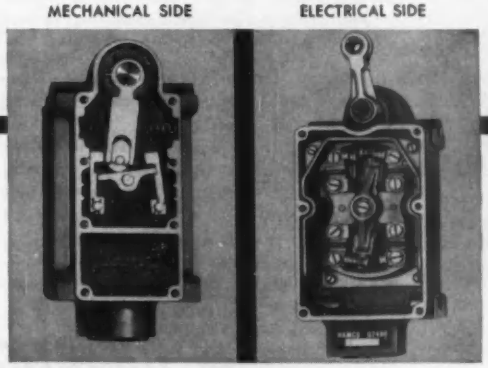
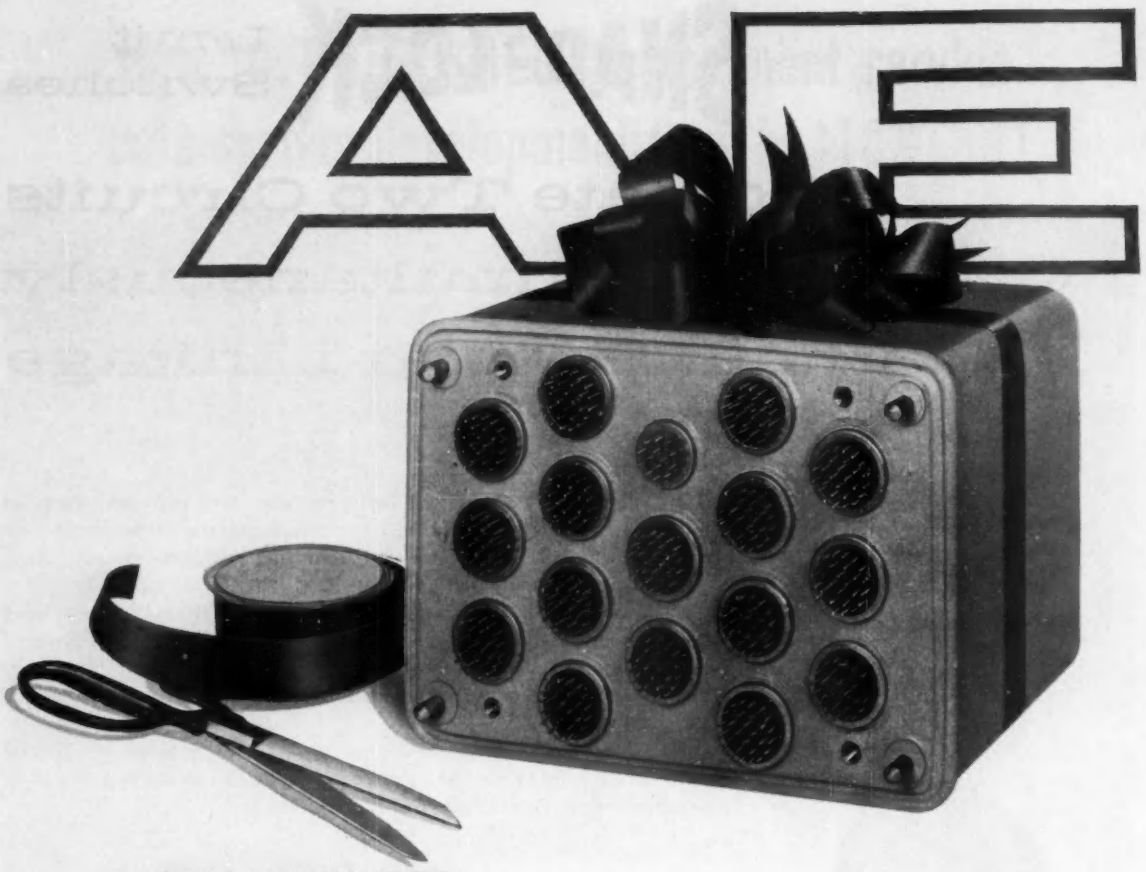
Sales Offices: Newark 2, N. J., Chicago 6, Ill., Detroit 27, Mich.

MECHANICAL SIDE ELECTRICAL SIDE



All Snap-Lock switches have separate enclosures within a single housing for the mechanical and electrical sides. Ample wiring space is provided and maintenance greatly simplified.

CIRCLE 111 ON READER-SERVICE CARD



TO THE ENGINEER

who likes his switching gift-wrapped

If you want your control functions prewired, hermetically sealed in a neat package, tested out, and as ready as instant coffee, you're listening to the right people.

Because AE has a gift for wrapping up relays and stepping switches in tidy control packages of your design—or ours, if you prefer.

For instance, the control package illustrated houses an AE Type 45 Rotary Stepping Switch wired to multiple-pin headers for direct plug-in (and we supply the properly oriented socket mounting plate). This particular job has 462 connections, and could just as readily be equipped with MS connectors for insertion in matching cable plugs.

The point is, we've been wiring telephone switchboards and automatic control devices for years, and have the technique down pat. So pat that it would probably cost you less to let *us* do the job.

Besides, AE engineers are past masters at designing complex switching circuits. You can leave it to them, if you wish, to dope out the least expensive way of accomplishing the most sophisticated switching.

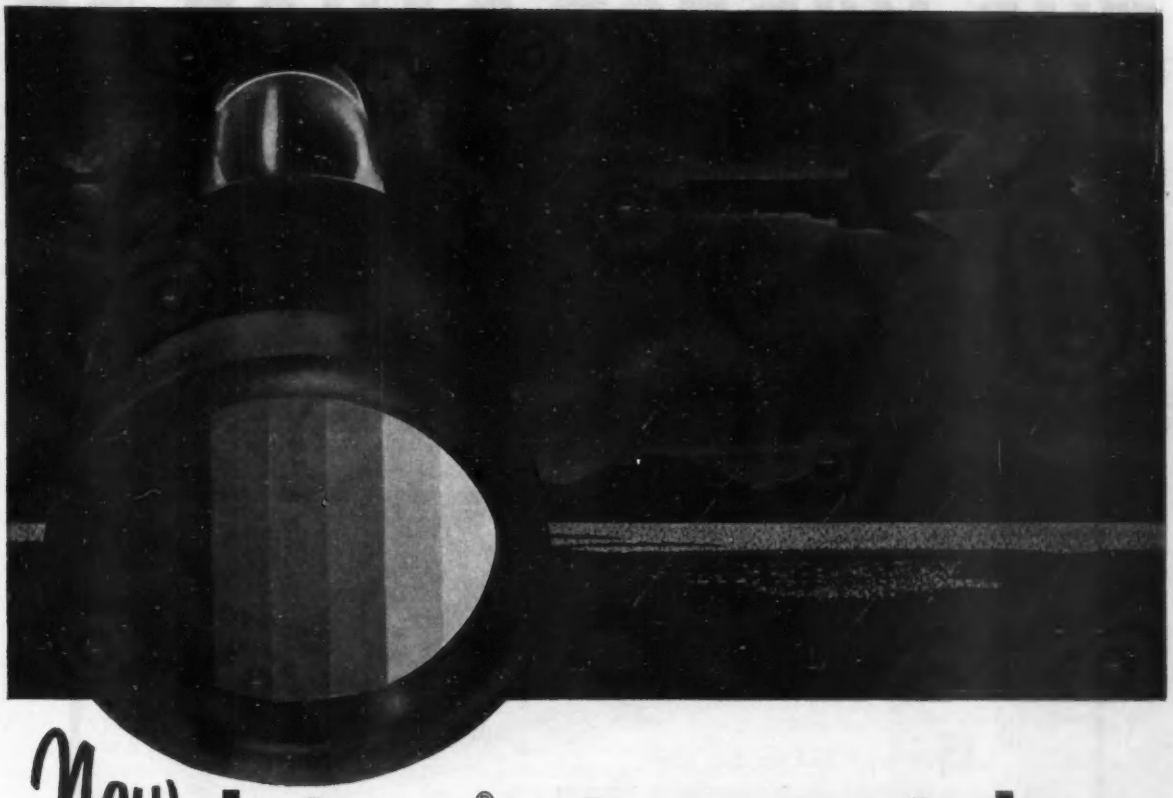
How about letting us in on *your* control problem? Just write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. Also ask for Catalog 4083: "Hermetically Sealed Relays and Switches."

AE CAN DO

AUTOMATIC ELECTRIC GENERAL SYSTEM

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS



New iatron® storage tubes

FOR GROUND OR ALL-WEATHER RADAR, SCAN CONVERSION SYSTEMS AND ADVANCED INSTRUMENTATION SYSTEMS

DISPLAY, STORE, ERASE - TONE OR LINE

Accurate, bright visual displays are produced for direct viewing and projection from electrical signals. High resolution enables gray tones to be produced in accordance with the amplitude variations of the input signals. High writing speeds and instantaneous erase are adjustable . . . storage is immediate.

This development in storage cathode-ray tubes is another advance by **I T T** . . . famous for tube technology for over half a century.

Write today for technical data on complete line of specialty, power and general purpose tubes.

TYPE	DIAMETER	FOCUS	DEFLECTION	WRITING SPEED IN /SEC	ERASING TIME	VIEWING TIME (MIN.)	RESOLUTION LINES/IN	BRIGHTNESS FT.-LAMBERTS
7172	2½" direct view	electrostatic	electrostatic	200,000	3 millisec.	30 sec.	25	1500
7173	4" direct view	electromagnetic	electromagnetic	200,000	3 millisec.	30 sec.	50	2800
7174	4" projection	electromagnetic	electromagnetic	200,000	3 millisec.	30 sec.	50	15,000
7175	5" direct view	electrostatic	electromagnetic	250,000	3 millisec.	40 sec.	80	2500
7176	5" direct view	electrostatic	electrostatic	250,000	3 millisec.	40 sec.	80	2500
7423	5" direct view	electrostatic	electrostatic	200,000	3 millisec.	30 sec.	25	2500

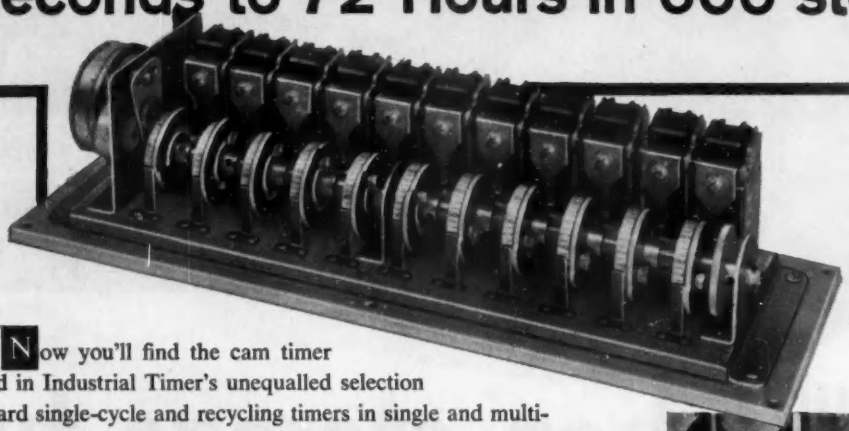
ITT *Components Division*

INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION
P. O. BOX 412, CLIFTON, NEW JERSEY

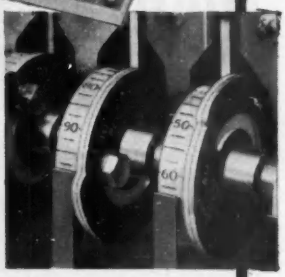
CIRCLE 113 ON READER-SERVICE CARD

THE WIDEST RANGE OF CAM TIMERS AND TIME CYCLES

2/3 Seconds to 72 Hours in 600 steps



Now you'll find the cam timer you need in Industrial Timer's unequalled selection of standard single-cycle and recycling timers in single and multi-switch types (up to 50 switches). Every model gives you 50 different overall time cycles, ranging from its lowest cycle up to 9 times that cycle. And standard cam construction lets you adjust ON and OFF periods from 2% to 98% of the total time cycle. Here is unsurpassed flexibility in cam timer selection and function.



If you don't find the timer you want in this unmatched range (a highly unlikely possibility), Industrial Timer's unique Timer Kit will help provide the exact timer you need at low cost. With this kit you can design your own prototype, and since the kit components are standard in our line we can reproduce your prototype—in quantity—*at no extra cost.*

For fast delivery on a standard or special Cam Timer check first with Industrial Timer. For more information ask for *Bulletin 200* Synchronous Motor Driven Cam Timers, *Bulletin 201* Multi-Cam Timer Kit, *Bulletin 202* Multi-Cam Switching Devices.

Industrial Timer's complete line of timers also includes: Time Delay Timers, Interval Timers, Running Time Meters, and Programmers. Bulletins describing these are available on request.

AFFILIATE—LINE ELECTRIC COMPANY

Timers that Control the Pulse Beat of Industry

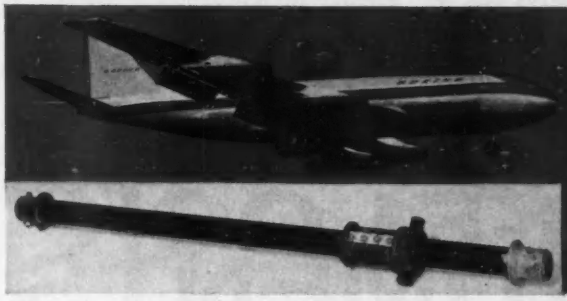
INDUSTRIAL TIMER CORPORATION

INDUSTRIAL TIMER CORPORATION

1409 McCARTER HIGHWAY, NEWARK 4, N. J.

added precision for your products

Beaver Ball Screws, Splines, Ways



Wing flaps of Boeing's monster 707 jet are actuated by Beaver ball screws. This is but one of more than 20 famous commercial and military aircraft that rely on Beaver, exclusively, for control of vital operating parts where precision, space, weight and power requirements are paramount design considerations.

This tape controlled skin mill, sion of Giddings and Lewis M Beaver Precision ball screws u vertical and horizontal position ing of the work chuck.

Gain optimum positioning control with system stiffness—Reduce 'stixion' to a minimum

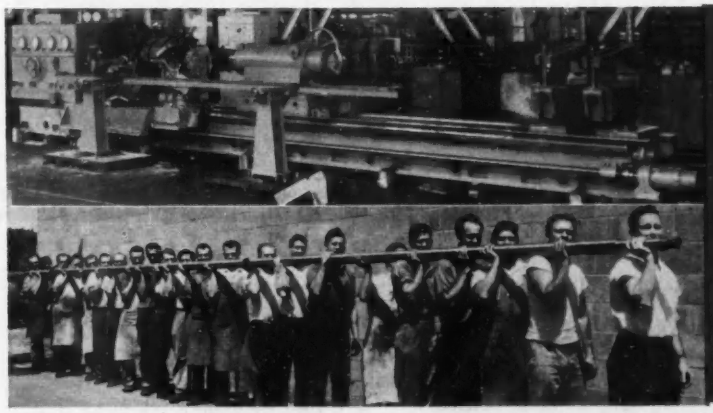
In a Beaver actuating device which employs rolling balls to eliminate friction encountered with the acme screw, engineers find many accompanying advantages. By preloading, a degree of system stiffness is accomplished to control motion with greater precision than ever before possible, while power and space requirements are reduced along with weight. Static friction closely approaches kinetic friction. Back-lash and surge are eliminated. Beaver ball screws rate better than 90% efficient.

Beaver occupies a dominant position in the area of ball screw application engineering. The company's facilities are planned not only for furnishing production requirements, but for assisting manufacturers through experimental and prototype stages. Size and quantity are no factor.

CONTRIBUTES TO NUMERICAL CONTROL EFFICIENCY

Beaver has made major contributions to the effectiveness of tape and card control of machine tools. In a minimum of space, with a minimum of power, Beaver ball screws provide precise control and repeatability in table feeds and other horizontal and vertical axes. As a result they are specified exclusively by an impressive list of leading machine tool manufacturers.

Our engineers are available to discuss your design problems with you.



The table of this giant steel mill roll lathe, built by E. W. Bliss Co. and designed by their Mackintosh-Hemphill Division, is actuated by a Beaver Precision ball screw that is probably the longest ever built, approximately 40 feet. The nut is preloaded to eliminate back-lash and increase system stiffness. The cross slide of this same machine is also controlled by a Beaver ball screw.

Beaver Precision Products INC.
CLAWSON, MICH.

CIRCLE 115 ON READER-SERVICE CARD

See Us at I.S.A.—Booth 125

Available now from Dymec! A complete array of versatile

"BUILDING-BLOCK" INSTRUMENTS FOR DIGITAL DATA SYSTEMS

Here is a practical approach that gives you, at no sacrifice in quality, a custom digital system at uniquely low cost.

Tne Dymec instruments shown here are specialized. Yet they are compatible, permitting a fully integrated system. Many can be used directly with printers, card punches, tape perforators and standard input/output equipment of other manufacturers. Dymec instruments are quantity-produced for obvious economies to you. Yet they are of finest quality, meeting the most rigid laboratory standards.

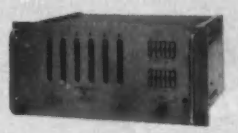
Many different systems can be assembled from these and other standard Dymec instruments. Dymec offers the instruments separately, as sub-systems, or as completely engineered, ready-to-use systems.

For specific information, call the Dymec engineering representative listed below, or write direct.

For further information on Dymec instruments or systems, contact:

ALABAMA: Huntsville, Bivins & Caldwell, Inc. Jefferson 2-5733 (Direct line to Atlanta). **ARIZONA: Phoenix,** Neely Enterprises, 641 East Missouri, CRestwood 4-5431. **Tucson,** Neely Enterprises, 232 So. Tucson Blvd., MAin 3-2564. **CALIFORNIA: North Hollywood (Los Angeles area.)** Neely Enterprises, 3939 Lankershim Blvd., TRiangle 7-0721. **Sacramento 14,** Neely Enterprises, 1317 - 15th Street, Gilbert 2-8901. **San Carlos (San Francisco area),** Neely Enterprises, 501 Laurel Street, LYtell 1-2626. **San Diego 6,** Neely Enterprises, 1055 Shafter Street, ACademy 3-8106. **CONNECTICUT: Bridgeport 8,** Yewell Associates, Inc., 1101 East Main Street, FOrest 6-3456. **COLORADO: Denver 10,** Lahana & Company, 1886 South Broadway, PEarl 3-3791. **FLORIDA: Fort Myers,** Lynch-Stiles, Inc., 35 W. North Shore Avenue, WYandotte 5-2151. **GEORGIA: Atlanta 5,** Bivins & Caldwell, Inc., 3133 Maple Drive, N.E., CEdar 3-7522. **ILLINOIS: Chicago 45,** Crossley Associates, Inc., 2711 W. Howard Street, SHeildrake 3-8500. **INDIANA: Indianapolis 20,** Crossley Associates, Inc., 5420 N. College Avenue, CLifford 1-9255. **MASSACHUSETTS: Burlington,** Yewell Associates, Inc., Middlesex Turnpike, BRowning 2-9000. **MARYLAND: Baltimore 15,** Horman Associates, Inc., 3006 West Cold Spring Lane, MOhawk 4-8345. **Rockville,** Horman Associates, Inc., 941 Rollins Avenue, HAzelwood 7-7560. **MICHIGAN: Detroit 35,** S. Sterling Company, 15310 West McNichols Road, BRoadway 3-2900. **MINNESOTA: St. Paul 14,** Crossley Associates, Inc., 842 Raymond Avenue, MIdway 6-7881. **MISSOURI, St. Louis 17,** Harris-Hanson Company, 2814 South Brentwood Blvd., Mission 7-4350. **Kansas City 30,** Harris-Hanson Company, 7916 Paseo Avenue, HIland 4-9494. **NEW JERSEY: Asbury Park,** I. E. Robinson Company, 905 Main Street, KEllogg 1-3150. **Englewood,** RMC Associates, 391 Grand Avenue, LOwell 7-3933. **NEW MEXICO, Albuquerque,** Neely Enterprises, 107

DY-2500 COMPUTING DIGITAL INDICATOR, variable gate time electronic counter permitting normalized direct reading with minimum controls, automatic setability. Measures frequency, period. Displays degrees/hr, gpm, RPM, etc.; also shows ratios of unlike variables. $1,330. One line readout, $1,505.

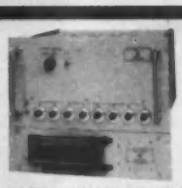


DY-2507 DUAL PRESET COUNTER, multi-purpose precision counter producing an output signal when either of two preset numbers is reached. Instrument is ideal for industrial control, sorting, packing, Go/No Go testing, control of coil winding, machine limits. $700 to $895.

DY-2542 TAPE PUNCH SETS record data from electronic counters on punched tape. High speed—recording rate 60 characters/second. Standard model: 5-level output code, 11 character format. Available with internal tape punch ($4480) or for use with external punch ($3240). For lower rates (20 characters/second) DY-2540 Scanner/Coupler, transfers counter data to serial entry machines. DY-2540, $890.

DY-2210 VOLTAGE TO FREQUENCY CONVERTER AND INTEGRATOR provides precision dc voltage measurements and integration with electronic counters. Multiple input ranges, either polarity. Input 0 to 1 v produces 0 to 10,000 cps output. $650. AC and remote models available.

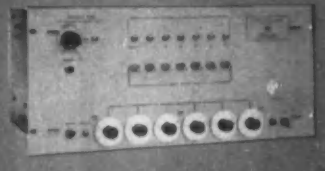
DY-2504A PHOTOELECTRIC TACHOMETER measures shaft speeds, revolutions, position from 0 to 10,000 RPM. Six models, offering 60, 100, 120, 180, 200 or 360 pulses/revolution. High resolution, low torque. $250.



DY-2512 CARD PUNCH COUPLER permits direct entry of counter information onto punched cards, eliminating manual key punch. Operates unattended. Readily connects Dymec or -hp- counters to IBM 523 Summary Card Punch. $1,890.

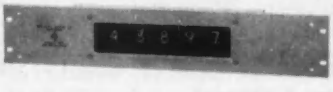
DY-2508 DIGITAL CLOCK continuously displays and provides parallel, multiple-contact closure, representing time-of-day in hours, minutes, seconds. 1-, 4- or 10-line code output. Inherent short time storage permits independent clock and recorder operation. $1,350 plus code wiring.

DY-2538 PROGRAMMED DIGITAL COMPARATOR. Unique, error-free comparison circuit, no drift or calibration; visual and electrical output; use with Go/No Go systems. Preset high and low tolerance limits selected electrically. Also manual-selection models. $950.



DY-2513 COUNTER SCANNER. Gathers multiple electronic counter data for printing on a single digital recorder. Simplifies simultaneous data measurements. For all Dymec or -hp- counters. $1,750.

DY-2530 BINARY/DECIMAL REGISTER. Universal output coupler connecting electronic counters to digital displays, comparators, printers, computers. Stores parallel binary-coded-decimal information in multi-contact relays. 10 models, dual or single output, 3 to 7 registers. $565 to $1,230.



DY-2533 DIGITAL DISPLAYS. Luminous, one-line indicator panels visually presenting multi-digit numeric data. Clear, high contrast, easy-to-read numerals. Five models, 3 to 7 digits. $140 to $300.

dy

DYMEC INC.

Electronic Instrumentation Systems

Dept. D8, 395 Page Mill Road
Palo Alto, California
DAvenport 6-1755

Data subject to change without notice. Prices f.o.b. factory.

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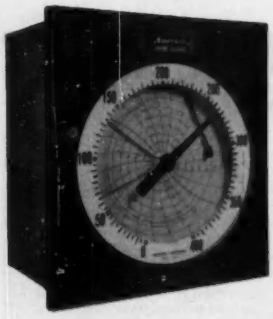
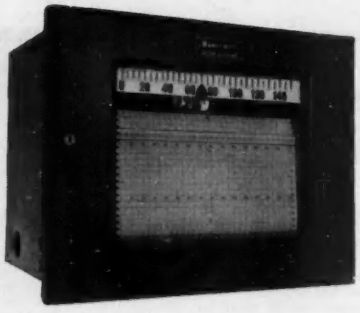
New Constant Voltage Unit makes *ElectroniK* instruments better than ever





All new Precision Line *ElectroniK* circular and strip chart instruments have the new Honeywell Constant Voltage Unit that accurately regulates d-c reference supply to the measuring circuit. No more batteries, standard cells or standardizing mechanisms . . . and no more of the problems they pose.

The Constant Voltage Unit delivers a constant, rectified voltage from line supply. It uses dependable Zener diodes and a reliable ambient temperature compensator.

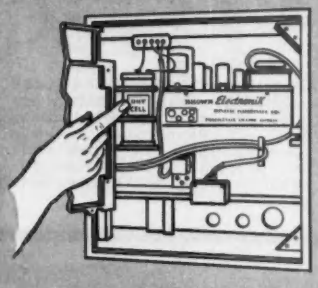
This latest improvement in *ElectroniK* instruments assures even greater dependability, and less maintenance, and is still another reason why *ElectroniK* instruments are your best value in measurement and control. Get full details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

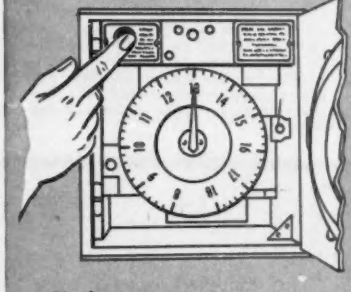
Honeywell

First in Control

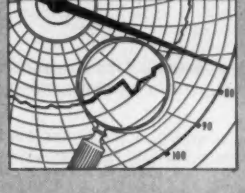
by eliminating these problems



No batteries **to replace . . . no recording or control deviation due to low battery voltage.**



No button **to push on the instrument for standardization . . . no false readings because of failure to standardize.**



No blanks or shifts **in the instrument's response to variables. You get complete continuity of recording and control.**

SQUEEZING HIGH POWER INTO small packages

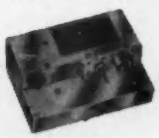
Unhampered by traditional thinking, TELECHROME engineers have developed an entirely new concept in telemetering equipment—unequalled in compactness, ruggedness and dependability.

TELEMETERING TRANSMITTERS

FM/FM or PDM/FM Crystal Controlled

215 to 260 Megacycles

Model 1472



4" x 1.5" x 2.7"
2 Watts

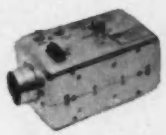
Model 1463

5 1/32" x 3 3/16" x 4"
15 to 30 Watts

Model 1462

6" x 4 1/4" x 3 3/4"
50 to 80 Watts

Model 1466A



6.5" x 4" x 3.25" RF Amplifier
2 watts in — 100 watts out

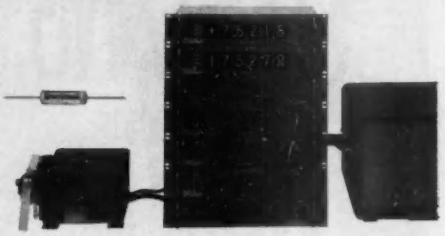
SUB-CARRIER OSCILLATOR.
Model 800C — 1.5" x 1.9" x 2.45"

Deviation stability ±1% of band width. Deviation linearity less than 1% of band width under all conditions measured from a straight line drawn between end points.

TELECHROME

Low cost, versatile DIGITAL SYSTEMS

for automatic testing of transistors resistors diodes and capacitors



Small E-I automatic digital systems provide many advantages. First, they cost less. This is primarily the result of large-quantity manufacture of modules which make up the E-I system. Cost is almost a linear function of performance capabilities desired in the system.

Second, they are exceptionally versatile. The E-I system can be expanded simply by adding appropriate modules. Typical systems presently in use measure resistance, capacitance, DC and AC voltages, DC/DC ratios, AC/DC ratios, AC/AC ratios and combinations of these. Measurements to four or five digits can be visually displayed and printed out at rates up to five readings per second. Operation can be semi- or totally automatic with go/no go comparison of values and programmed readout at periodic intervals. Scanners can be provided for scanning thousands of single and multi-wire input channels. In brief, the E-I system has an extensive scope of operating capability.

Third, E-I systems provide unmatched reliability. Where practicable, circuits are totally transistorized. The use of etched, plug-in circuit boards, and modular internal construction make maintenance checks and in-plant repairs easy.

Typical E-I system for evaluating components—includes 100 channel input signal scanner. Can digitize DC voltage, resistance, AC voltage and DC/DC voltage ratio analogs. Digital equivalents are recorded on strip printer for "quick look" data and on punch paper tape for additional data reduction by digital computer.

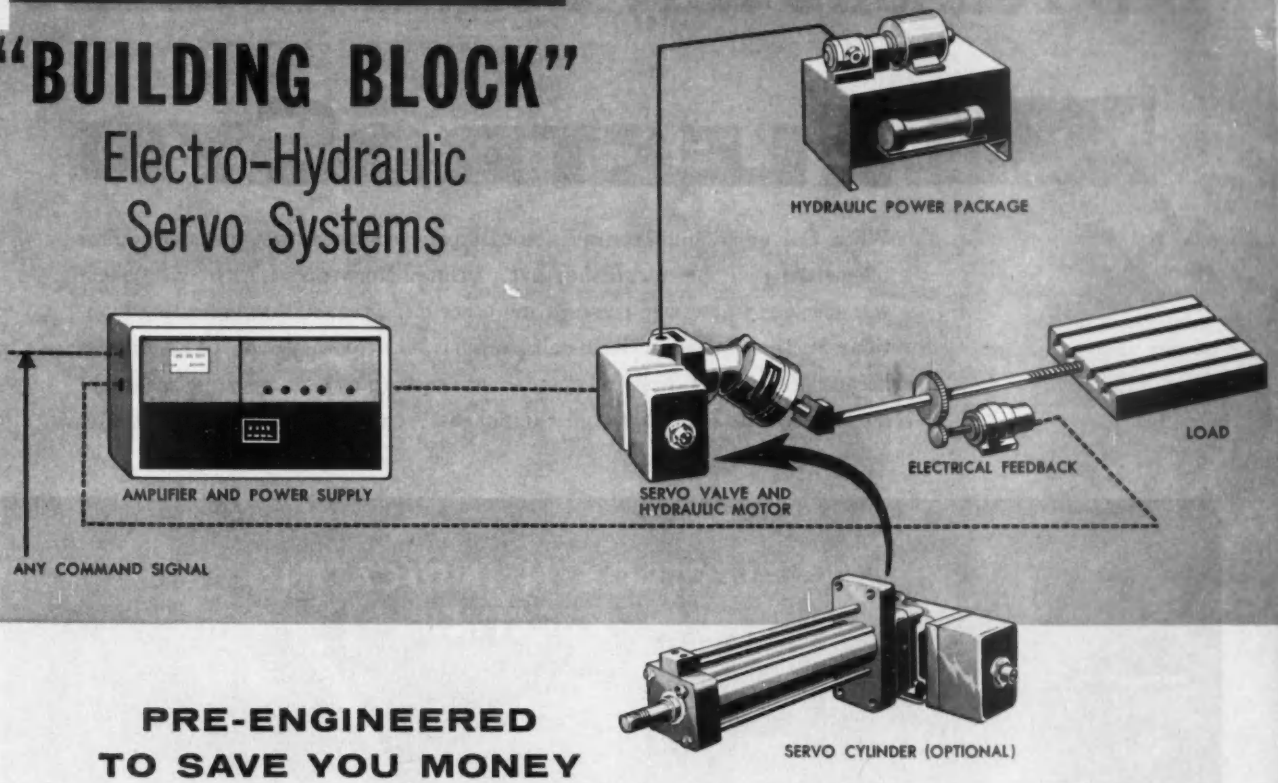
Lower cost, maximum versatility and greater reliability—if you want these advantages in your component test system, contact your nearest E-I representative. He can give you complete information or answer any specific questions you may have.

Electro Instruments, Inc.

3540 AERO COURT
SAN DIEGO 11, CALIF.

A NEW CONCEPT

"BUILDING BLOCK"
Electro-Hydraulic Servo Systems



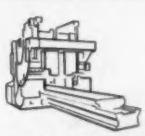
PRE-ENGINEERED TO SAVE YOU MONEY

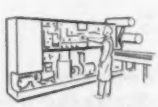
Standard hydraulic and electrical components are now pre-engineered into a series of complete and dependable Electro-Hydraulic Servo Systems. Vickers has the most extensive line of individual "building block" components available for such systems. Inherent "trim flexibility" makes possible systems which will satisfy a very wide range of application . . . at only a fraction of the cost usually incurred in specially engineered systems. A very substantial saving in lead time is now possible.

Vickers "Building Block" Closed Loop Servo Systems have proved their merit on machine tools, fabricating machines and processing equipment. The amplifier is precisely matched to the servo valve torque motor. The work load requirement is continuously monitored by electrical feedback devices to insure that directions (command signals) are accurately followed at all times.

Positional accuracy of better than .001 is obtainable with a hydraulic motor and lead screw. In many position applications, cylinders can be used with similar accuracies. Velocity can be maintained within one or two rpm. In addition to position and velocity controls now in service, constant horsepower and constant tension systems soon will be available. Any command signal may be used with these systems . . . from a simple potentiometer to complete numerical control. For further information, ask for Engneering Bulletin No. 59-75.

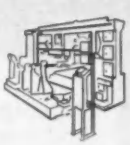
wide range of applications


CUTTING MACHINERY

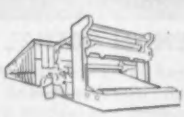

FOOD PROCESSING

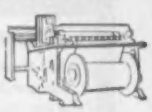
FORMING MACHINERY

TEST STANDS


FABRICATING

ANTENNA DRIVES


PAPER MACHINERY


TEXTILE MACHINERY

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Machinery Hydraulics Division
ADMINISTRATIVE and ENGINEERING CENTER
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ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921

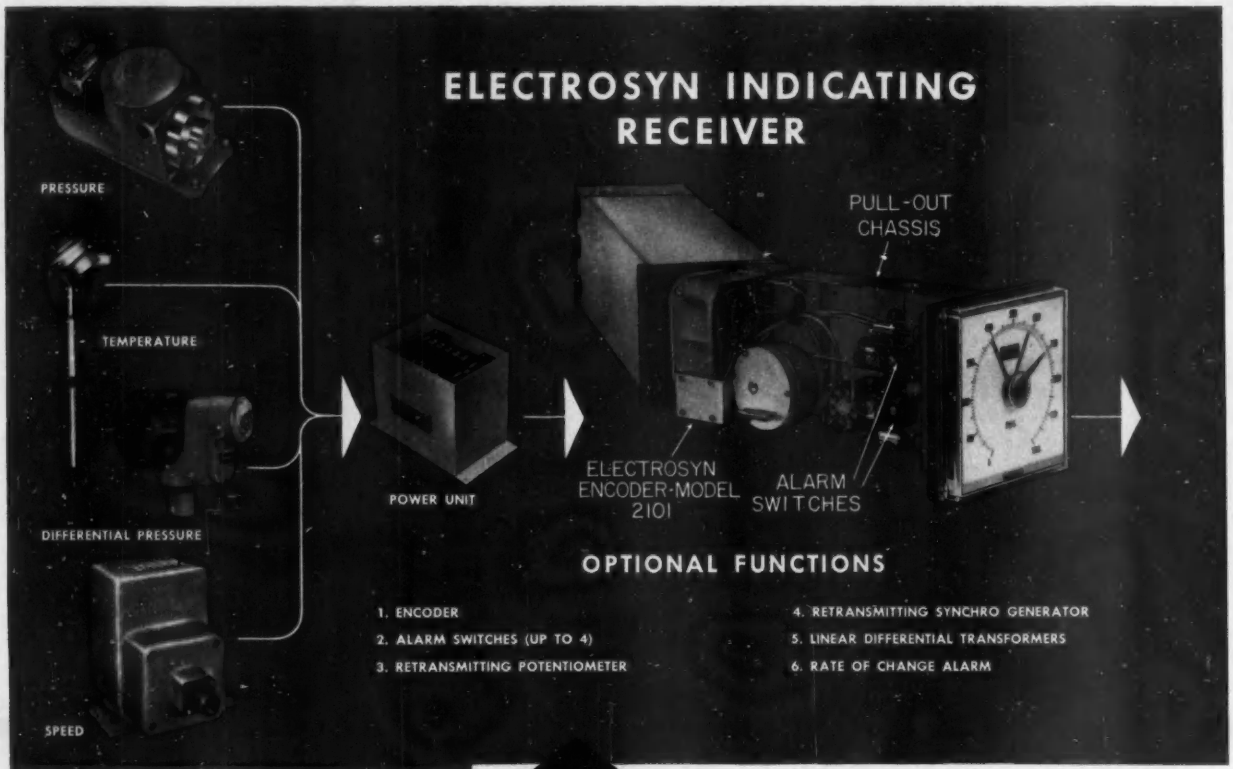
CIRCLE 120 ON READER-SERVICE CARD

3 reasons why Columbia-Gulf

NC NORWOOD CONTROLS

ELECTROSYN

When Columbia-Gulf Transmission Company engineers first installed digital telemetering equipment on their gas pipelines, Norwood's ElectroSyn System was specified to perform pressure and other measurement and indicating functions. Success of these initial installations has led to repeat orders for ElectroSyn because its low operating and maintenance costs (plus high reporting accuracy) far outweigh its somewhat higher initial cost... as the following facts indicate.



PROVEN IN ACTUAL SERVICE

The Norwood ElectroSyn system has proved its compatibility with the leading digital telemetering systems and supervisory control systems. Actual installations are currently helping to cut operating costs for the following well-known users:

SERVICE PIPE LINE CO., TEXAS EASTERN TRANSMISSION CORP., COLUMBIA-GULF GAS TRANSMISSION CO., EL PASO NATURAL GAS CO., SOUTHERN PACIFIC PIPE LINES, INC., ARABIAN AMERICAN OIL CO., LAKEHEAD PIPE LINE CO.

The System

Error signal is amplified by a magnetic servo-amplifier (which can be located up to 4 miles from transmitter). Signal voltage is compared with output from a servo-motor driven feedback ElectroSyn Signal Generator. Pointer on indicator turns until signal and feedback balance and then entire system ceases to move until next transducer signal change.

Write for ElectroSyn Bulletin B258C Norwood Controls Unit, Detroit Controls Division, **938** Washington St., Norwood, Massachusetts.

Transmission Company specified

RELIABILITY

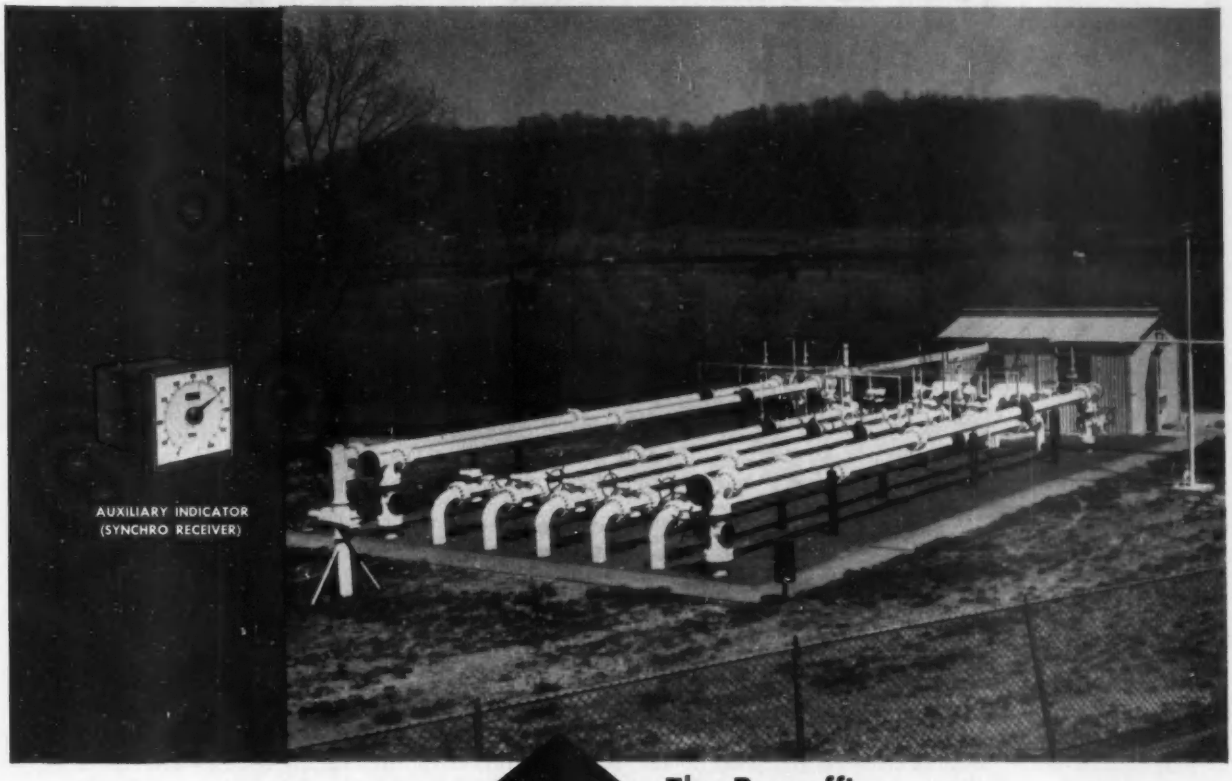
No vacuum tubes, no brush contacts, no moving parts at all under equilibrium conditions. Wear due to friction is so much reduced that truly automated pipeline monitoring and control become both practical and economical.

ACCURACY

Pressure, flow and other data are reported with close to 1% of full-scale accuracy. This not only permits lower safety margin requirements and greater throughput under conditions of high demand but also ensures maximum operating efficiency at lower pipeline pressures.

ECONOMY

results from both accuracy *and* reliability. ElectroSyn's trouble-free operation virtually eliminates breakdowns common in less reliable systems and also saves the cost of rushing repair personnel to remotely located stations.



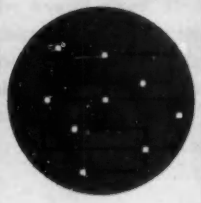
The Pay-off!

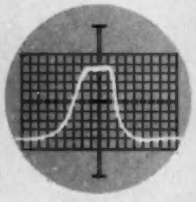
In remote locations like this Columbia-Gulf Transmission Company station at Leach, Kentucky, it usually takes many hours to get repair personnel to the job in the event of breakdown. ElectroSyn reliability virtually eliminates the costs of both repair and downtime. Routine maintenance costs are slashed, too.

AMERICAN-Standard
DETROIT CONTROLS DIVISION

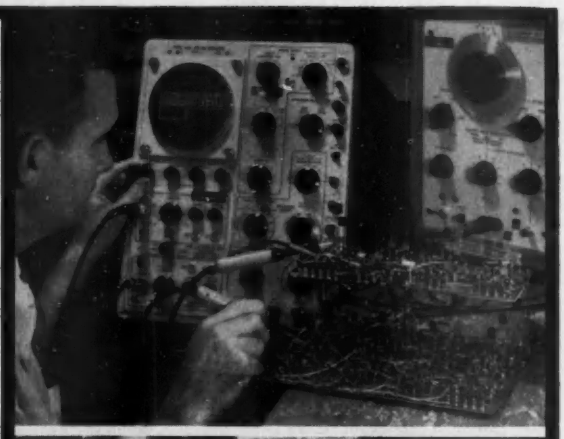
CIRCLE 121 ON READER-SERVICE CARD

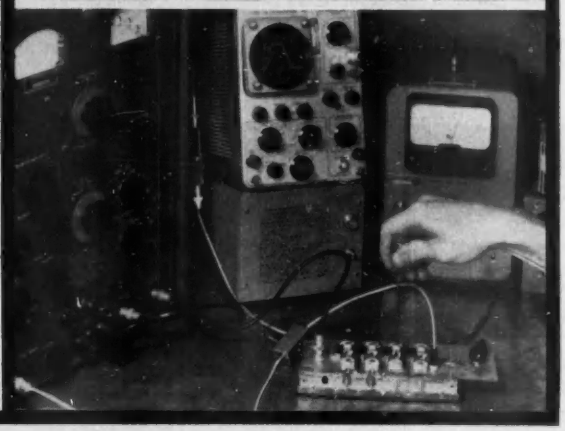
CAREER OPPORTUNITIES AT TI





CIRCUIT DEVELOPMENT ENGINEER





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Interviews will be held in your area soon. If you have an Electrical Engineering degree and/or knowledge of transistor circuitry, please send a resume to

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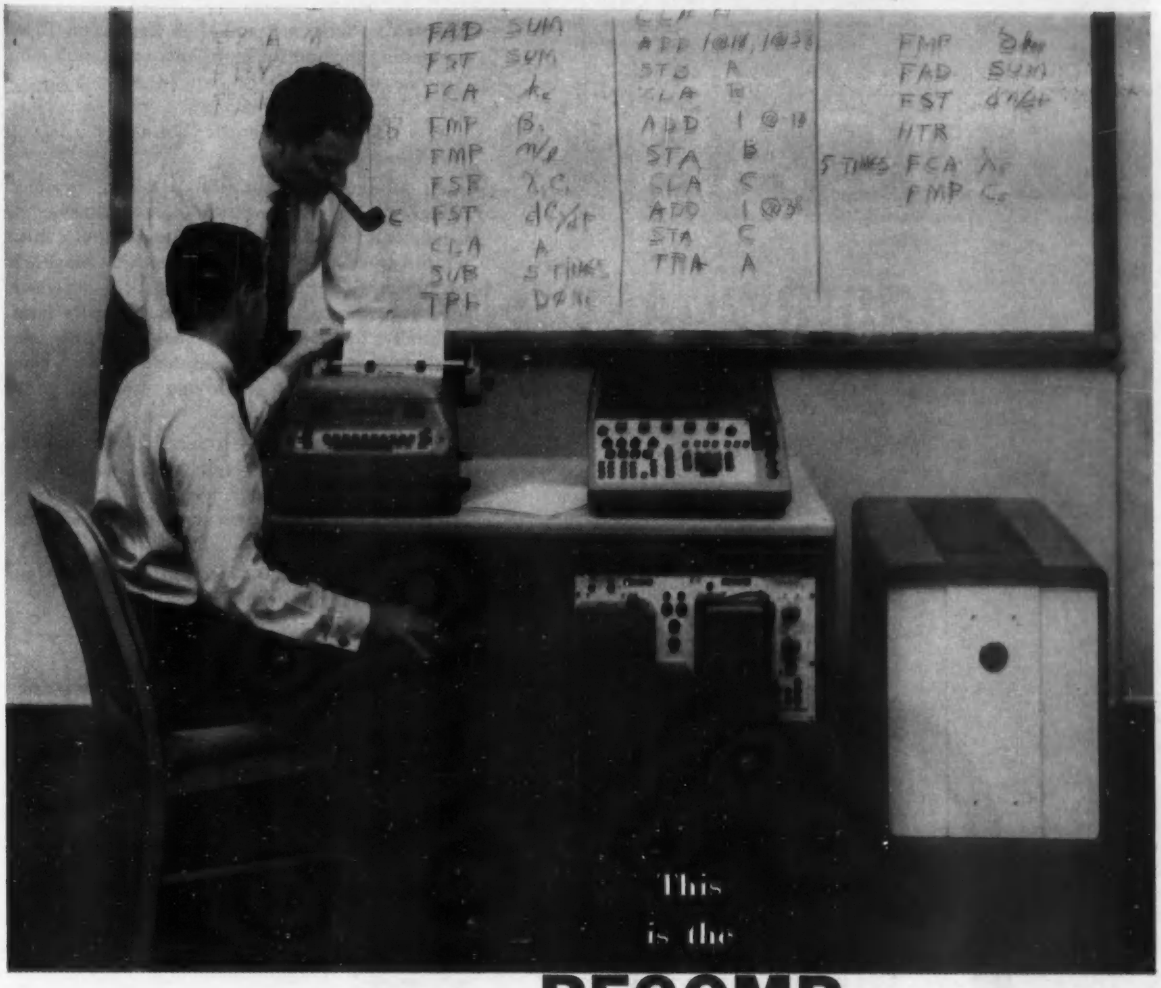

RECOMP

digital computer

It has a storage capacity of 8,000 instructions ... and it's low-priced

No problem is too complex to tackle with Recomp—and you can afford to put it wherever it's needed to break up computer-time bottlenecks. It's easy to use, too; engineers quickly learn to program their own problems. *Other Recomp features:* a command structure of 49 arithmetical and logical commands—including 9 built-in floating point commands ... standardized teletype tape configuration ... all-transistorized ... 400-character-a-second input ... electronic console that puts all basic controls within fingertip reach ... simplified coding. Recomp gives you far more capacity, versatility, and trouble-free service for your money. It's available for sale or lease. *There's no extra equipment to buy ... no cost of installation.* Please write for complete literature. Industrial Products Division, Autonetics, Dept. 39, 3584 Wilshire Boulevard, Los Angeles 5, California.

This engineer learned to program Recomp in two days

Digital computers by Autonetics

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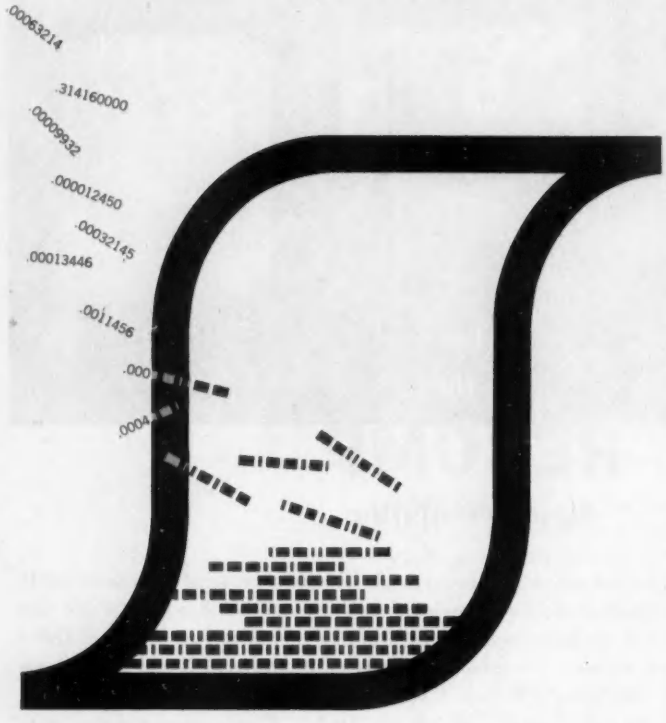
Other offices: Dayton, Ohio; Washington, D.C.

TAPING CRITICAL INFORMATION?

"SCOTCH" Brand high potency oxides let you pack more bits per inch!

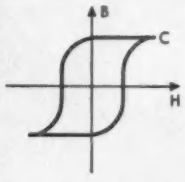


Every day SCOTCH Brand High Resolution Tapes are getting the nod for more instrumentation jobs. The reason? Performance. In taping high frequency data, the sharper resolution lets you pack more pulses to the inch—a greater density of information to each foot of tape.

At the root of this advance are the high potency oxides used in the magnetic coating. The higher magnetic retentivity of these oxides—about a third more than standard—offers distinct advantages. It permits the use of a thinner magnetic coating which may be combined with a thinner polyester base. Naturally, this means a more flexible tape — one that conforms for more intimate tape-to-head contact, automatically improving resolution in the taping of high frequencies.

Even so, you don't have to sacrifice output in low frequencies. For in addition to the marked increase in sensitivity to short wave lengths, SCOTCH Brand High Resolution Tapes show some increase in sensitivity even to long wave lengths.

These more flexible tapes cut drop-outs, too. With better tape-to-head contact, there's less chance that a stray bit of dust can sneak between tape and head to cause a drop-out. The superior magnetic properties of SCOTCH Brand High Resolution Tape No. 159 show up in oscilloscope tests—producing a good squared-up hysteresis curve like that shown at the right, and symbolically illustrated at the left.



Whatever your application—data acquisition, reduction or control programming—you can count on SCOTCH Brand technology to create tapes of higher uniformity and reliability for error-free performance.

SCOTCH Brand High Output Tape No. 128 provides the sensitivity for good output in low frequencies, even under extremes of ambient temperature. SCOTCH Brand Sandwich Tapes No. 188 and 189 offer extremely long life and reduced head wear in digital work and many AM, FM and PDM applications. Finally, for top performance at low cost per foot, SCOTCH Brand Instrumentation Tapes No. 108 and 109 remain the standard for the industry.

Where there's no margin for error, there's no tape like SCOTCH Brand. For more details, mail reader inquiry card or write Magnetic Products Div., Dept. MBS-99, 3M Co., St. Paul 6, Minn.

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SCOTCH BRAND MAGNETIC TAPE

FOR INSTRUMENTATION

MINNESOTA MINING AND MANUFACTURING COMPANY
... WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY

DELCO RADIO

NEW POWER TRANSISTORS

MILITARY–COMMERCIAL

	2N1168	2N392	2N1011	2N1159	2N1160
V_{cb} max.	50	60	80	80	80 volts
I_c max.	5	5	5	5	7 amp.
I_{co} (V_{cc} 2 volts) Typical 25 °C.	65	65	65	65	65 μa.
HFE (3 amp.)	–	60-150	30-75	30-75	–
HFE (5 amp.)	–	–	–	–	20-50
AC Power Gain (I_c = 0.6 amp.)	37 DB	–	–	–	–
V_{ceo} (I_c = 1 amp.)	40 typical	50 typical	60 min.	60 min.	60 volts min.
Thermal Gradient max.	1.5	1.5	1.2	1.2	1.2° c/w

Delco Radio rounds out its power transistor line with this new 5-ampere germanium PNP series. Types 2N1168 and 2N392 are specially designed for low-distortion linear applications, while 2N1159 and 2N1160 are outstanding in reliable switching mode operations.

Type 2N1011 is designed to meet MIL-T-19500/67 (Sig. C). It joins 2N665, MIL-T-19500/68 (Sig. C); 2N297A, MIL-T-19500/36 (Sig. C) and JAN2N174, MIL-T-19500/-13A to provide a selection for military uses.

Write today for engineering data on Delco Radio's line of High Power Transistors.

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DEPENDABILITY
RELIABILITY

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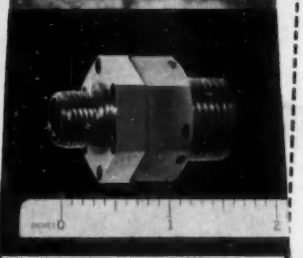
FOR
ROCKET ENGINES

ACCURACY
IN SPITE
OF
BLAST



STATHAM P285TC
Oil-Damped Pressure
Transducer

This new, extremely rugged oil-damped miniature pressure transducer easily survives the step function pressures and blast pressures of rocket engine environments. Measures pressures from 0-50 to 0-1000 psi with the infinite resolution, accuracy and reliability of unbonded strain gage instruments. Absolute and gage models. Write for Data File CE-603-2.

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TINY
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GAGES

STATHAM CA-9
Strain Gage
Signal Amplifier

Through the use of modern design techniques, Statham has succeeded in drastically reducing the size and weight of strain gage signal amplifiers. Completely transistorized, the CA-9 is more reliable in adverse environments than larger and heavier amplifiers, and retains the precision needed in current aircraft and space vehicles. Write for Data File CE-601-3.

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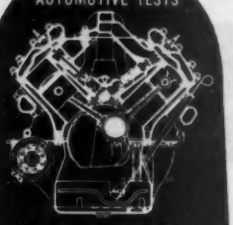
IN
AUTOMOTIVE TESTS



OUTLIVES
ENGINE
AFTER
ENGINE

STATHAM P10
Pressure Transducer

In automatic transmission pressure tests run by one of the world's leading auto manufacturers, this rugged pressure transducer has outlived engine after engine throughout more than two years of 24-hour-a-day test operation. Built to stand rough handling and mechanical overload in many applications, the P10 affords the accuracy, reliability and infinite resolution of an unbonded strain gage instrument. Write for Data File CE-604-2.

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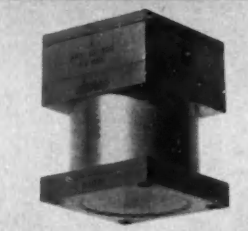
CONSTANT OR VARYING MEASUREMENT ALONG 3 AXES



STATHAM A63
Triaxial Accelerometer

This single package incorporates measurement of linear acceleration along three accurately pre-aligned, mutually perpendicular axes. Reads constant as well as varying acceleration. Meets exacting airborne specifications. Exhibits the long service life, infinite resolution and electrical calibration features of Statham unbonded strain gage transducers. For further information write for Data File CE-755-1.

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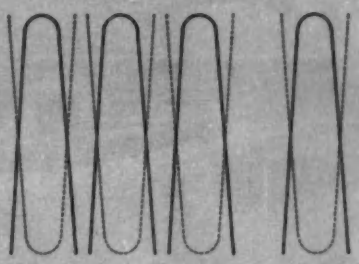
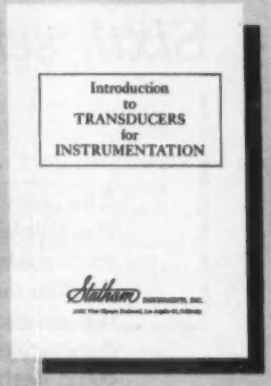


LEADERSHIP IN MEASUREMENT

Illustrating Statham leadership in measurement, the products shown at left are a random sampling of the many Statham devices that are widely used in missile, aircraft, industrial and nuclear instrumentation.

Researched and fabricated by the pioneer of the unbonded strain gage, such accurate, rugged sensing instruments as these have been privileged to help make the U.S. space and nuclear power programs a dynamic reality.

Recognizing that no one line can include the ideal instrument for every purpose, Statham has further exercised the responsibility that devolves upon leadership by preparing an objective, illustrated booklet entitled "Introduction to Transducers for Instrumentation." Brief but scholarly, it will aid instrumentation and project engineers in surveying all 16 major transduction principles, including but not limited to those used in Statham products.



Write for it on your company letterhead. Other information on specified instrumentation areas or problems will be included at your request.

Visit Statham Booth 747 at the I.S.A. Show.

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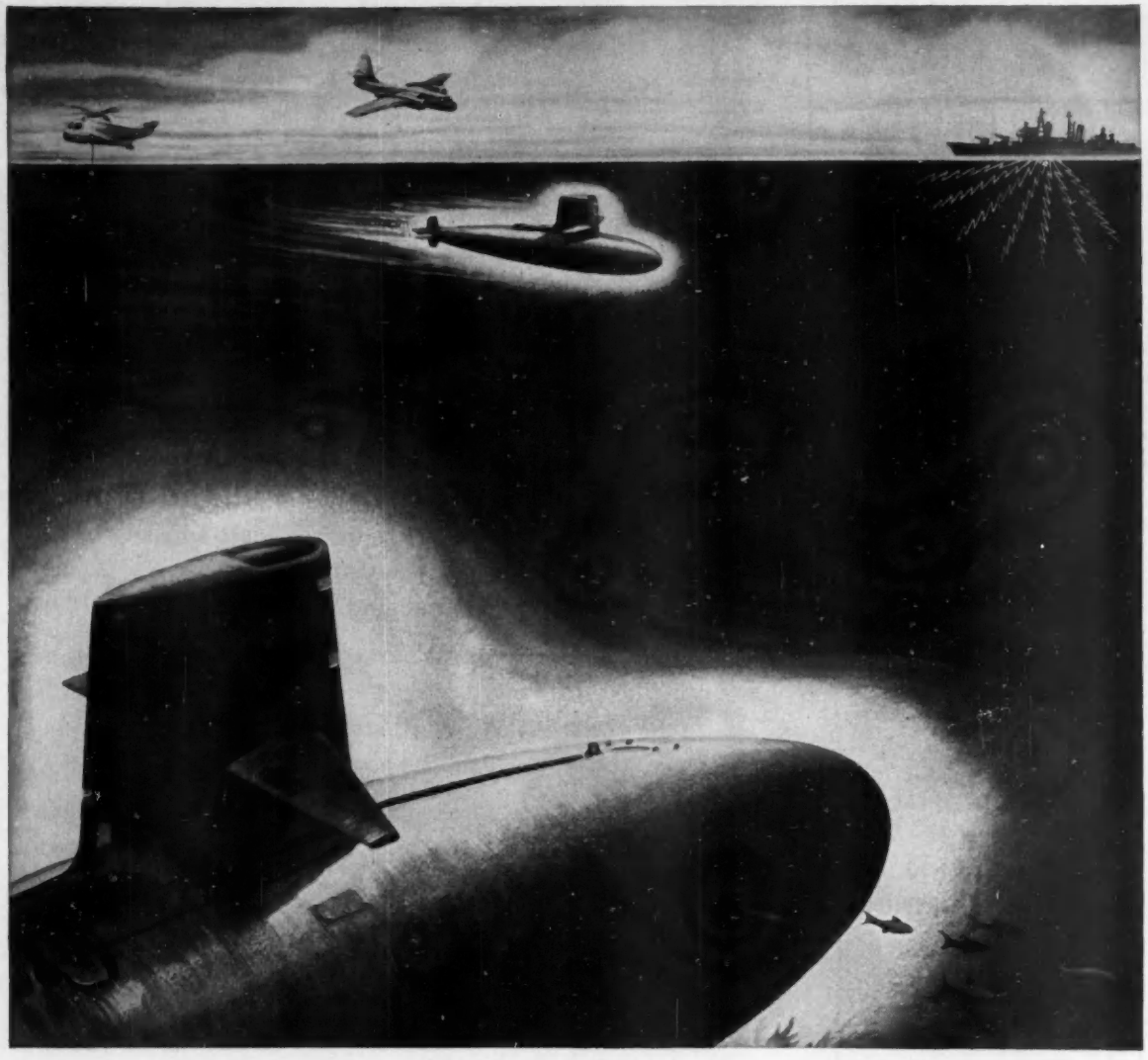

Sixth sense for the hunter-killers

"Our greatest need is for longer range detection equipment and the weapons to give us the kill capability by the time we have the extended range search and identification gear."—Rear Admiral John Thach, Commander Anti-Submarine Defense Group ALFA.

The Navy's Special Task Group Alfa—the Hunter-Killers who defend against enemy submarines—must find faster and deadlier means of detecting and destroying enemy submarines in time of war. Submarines launching nuclear warheads could destroy major cities and military installations in a matter of minutes.

ARMA has accepted the challenge to provide for the Navy's greatest ASW need, insuring our future by swifter and surer elimination of the undersea threat.

This and other top-priority projects are underway at ARMA—longtime developer of new concepts and equipment for the American military.

ARMA, Garden City, N.Y., a division of American Bosch Arma Corporation . . . The Future Is Our Business.

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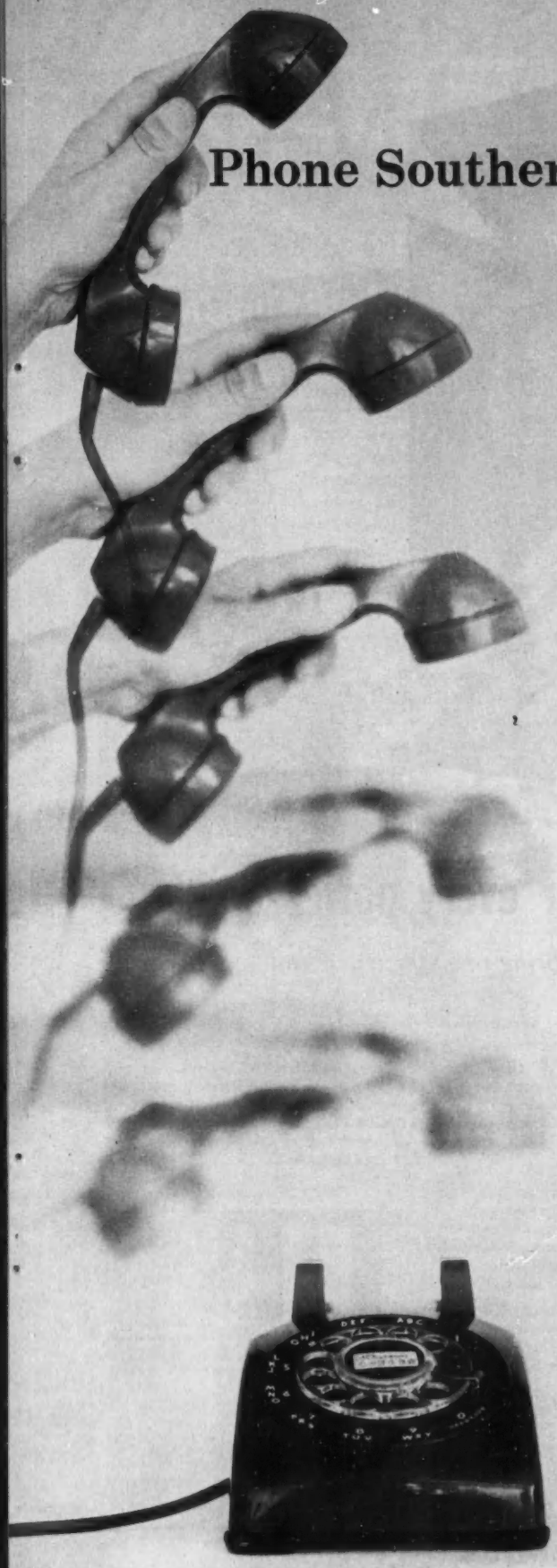
AMERICAN BOSCH ARMA CORPORATION



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Ask for Mr. B. P. Ramstack

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Electronic Scanning Radars—to develop new advanced applications for 3-dimensional radar.

Data Processing Systems—to design computers which monitor activity of hundreds of aircraft, and direct the assignment of defense weapons.

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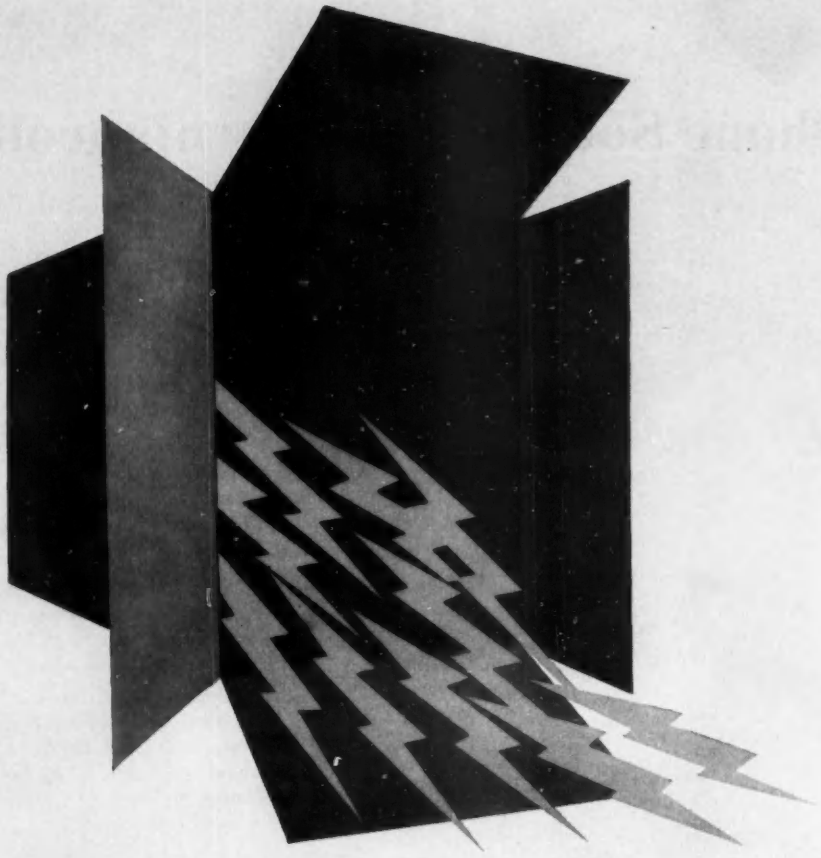

Power in "packages"—for every power need

ITT's unique concepts in power conversion bring new efficiency and economies

PUSH a button—throw a switch! Out of ITT "packages" of power come the exact voltages for countless electronic applications.

Power in static "packages" provides vital military equipment with the utmost in dependable power supply—gives industry uninterrupted DC service and saves the cost of DC generators and their upkeep.

ITT's new idea in power supply

Among the many important areas where ITT "package" power systems are meeting the highest standards of performance are space and aviation.

ITT "packaged" power controls landing gear, operates navigation, communication, counter-measures, missile-launching and the many other systems that give our jets combat capacity.

All DC power for the supersonic B-58 comes from an ITT integrated power system—a *first* in the industry.

ITT-designed power systems serve the B-52 and other famous aircraft, as well as ground-based and seaborne electronic systems.

"Building blocks" for any DC output

From these major contributions to military power supply, ITT System companies have developed complete capabilities for engineering modular-type, "building block" power systems for the most sophisticated needs of industry.

ITT "packaged" power concepts embrace every field of manufacturing. Hundreds of equipment designs are ready at ITT to meet the broad and expanding range of today's DC applications—from the simplest DC motor to the most complex techniques for automation and data processing systems.

If you require DC output for *any* purpose, investigate these unmatched capabilities. For complete information, write to ITT Industrial Products Division, 15191 Bledsoe Street, San Fernando, California.

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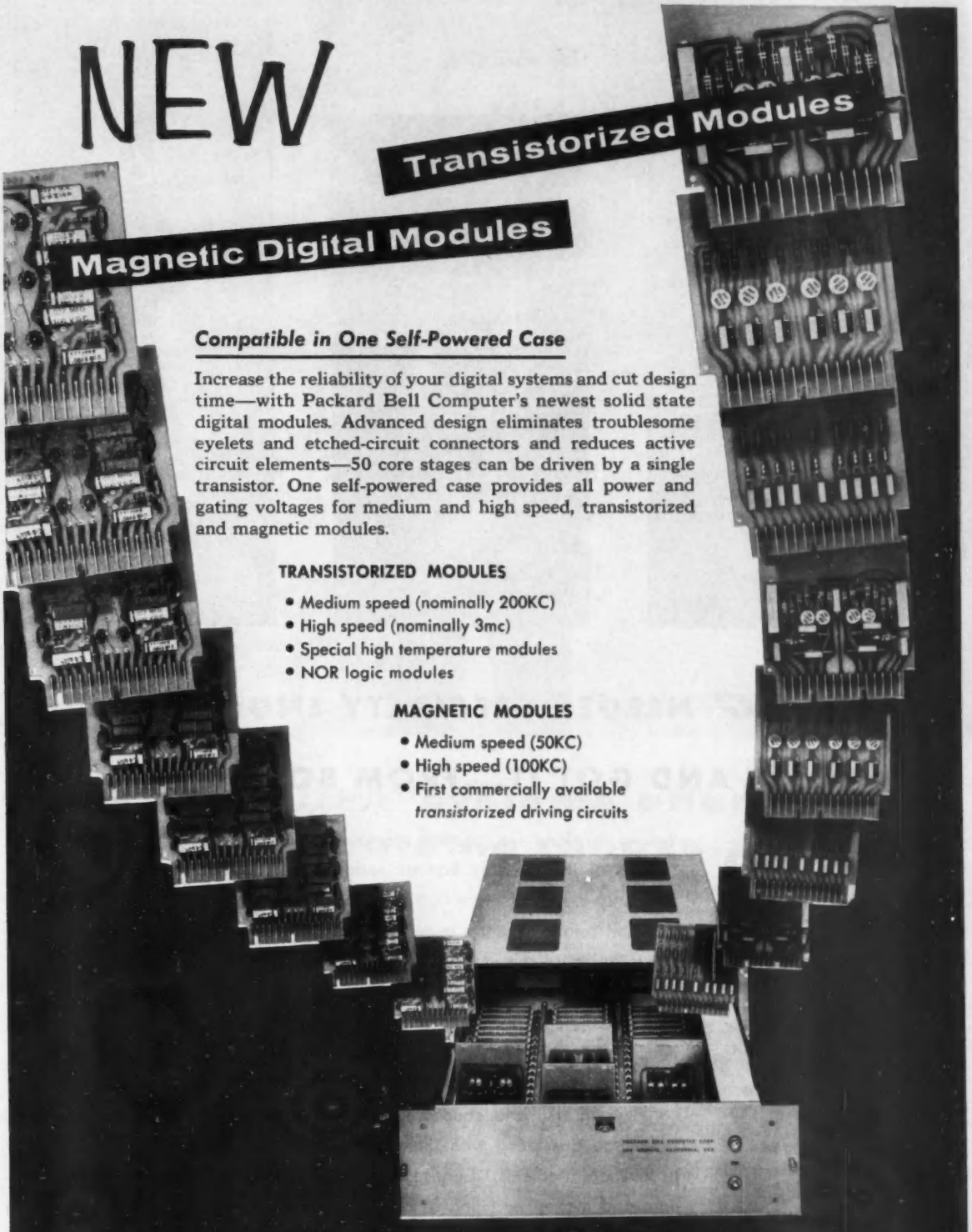
 CIRCLE 127 ON READER-SERVICE CARD

NEW

Transistorized Modules

Magnetic Digital Modules



Compatible in One Self-Powered Case

Increase the reliability of your digital systems and cut design time—with Packard Bell Computer's newest solid state digital modules. Advanced design eliminates troublesome eyelets and etched-circuit connectors and reduces active circuit elements—50 core stages can be driven by a single transistor. One self-powered case provides all power and gating voltages for medium and high speed, transistorized and magnetic modules.

TRANSISTORIZED MODULES

- Medium speed (nominally 200KC)
- High speed (nominally 3mc)
- Special high temperature modules
- NOR logic modules

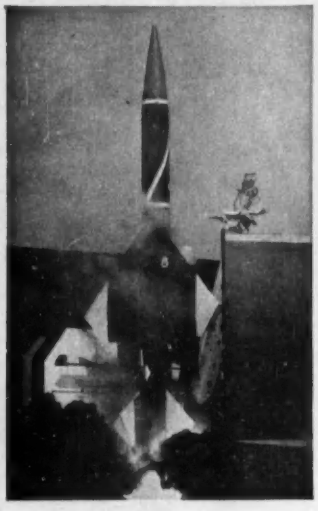
MAGNETIC MODULES

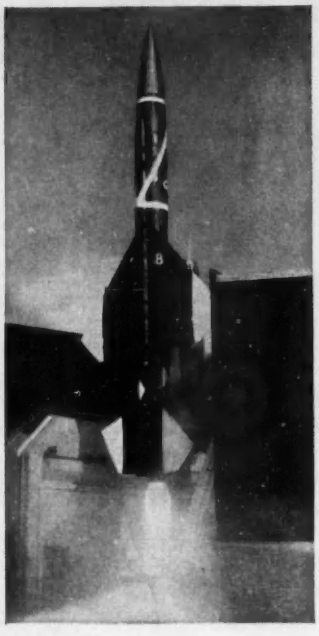
- Medium speed (50KC)
- High speed (100KC)
- First commercially available *transistorized* driving circuits

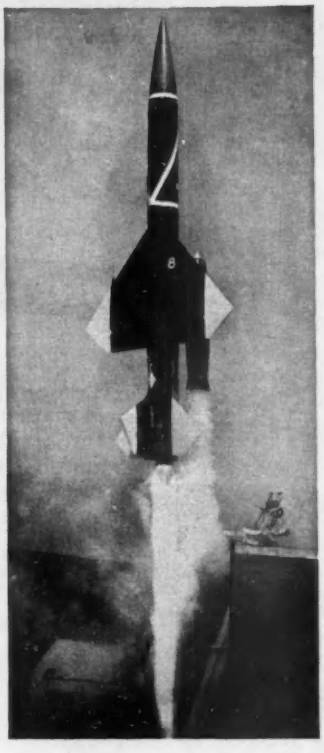
PACKARD BELL COMPUTER CORP.

CIRCLE 128 ON READER-SERVICE CARD

BORG ...a world of ideas... *that work*







BOEING NEEDED SPECIALTY ENGINEERING...

AND GOT IT...FROM BORG

A FEW BORG DEVELOPMENTS

- FREQUENCY STANDARDS
- AIRCRAFT INSTRUMENTS
- PRECISION POTENTIOMETERS
- MULTI-TURN COUNTING DIALS
- FRACTIONAL H. P. MOTORS

Boeing Airplane Co. needed special potentiometers for the guidance systems of their deadly Bomarc surface-to-air missiles. The necessary potentiometers had to withstand severe vibration and shock and still retain uncanny accuracy within extreme tolerances. The solution to this difficult reliability problem? The design, development and production facilities of the Borg Equipment Division of the Amphenol-Borg Electronics Corporation. The result? Specially designed potentiometers exceeding all required specifications. Many industry leaders have found that they can depend on Borg engineering skill and cooperation. Call on Borg when you are faced with difficult design, development or production problems. Chances are you'll save a good deal of time and money and find it makes good sense to call on Borg. Write for our new facilities brochure.

BORG

BORG EQUIPMENT DIVISION
AMPHENOL-BORG ELECTRONICS CORPORATION
JANESVILLE, WISCONSIN

recti/riter® systems offer you the widest recording ranges available

Versatile "recti/riter" recorders, both Single and Dual channel, have established new standards for *reading ease, full-scale accuracy,* and *up-front operator conveniences.* Now, the applicability of the "recti/riter," or other graphic recorders of one-milliampere sensitivity, is extended to the widest practical limits by the use of Series 300 accessories, which presently include models:

301 DC AMPLIFIER
350 MULTI-VOLTAGE MONITOR
351 AC MULTI-CURRENT MONITOR
352 LINE FREQUENCY MONITOR
353 LINE VOLTAGE MONITOR
354 LINE CURRENT MONITOR
333 LINE SERVICE MONITOR
(a single-package combination of 352, 353, and 354)

Only the "recti/riter" systems, recorders and matching accessories, offer these wide ranges for recording electrical parameters:

10 millivolts to 1000 volts . . .
500 microamperes to 1000 amperes . . .
Monitor standard frequencies—40, 60, 400 cps.

FULL SCALE RANGES—Accessory scales give quantities per division equal to decimal multiples or sub-multiples of 1, 2, and 5 in keeping with standard 50-division chart of recorders.

ACCURACY—Combined recorder-accessory response departs from true value at any point not more than 2 per cent of the full scale value.

POWER REQUIREMENTS—No auxiliary power required for transducer accessories . . . a 45-volt battery or optional AC supply is used with the DC Amplifier.

SIZE—Aluminum cases 2½" H., 7½" W., 10" D. (Monitors may be mounted inside as integral part of recorders.) Mountings are available for relay racks, flush mounting, portable, or desk use.

To select the "recti/riter" recorder-accessory system that meets your exact measurement requirements, let TI give you complete technical assistance . . . write or call today!

TEXAS INSTRUMENTS
INCORPORATED
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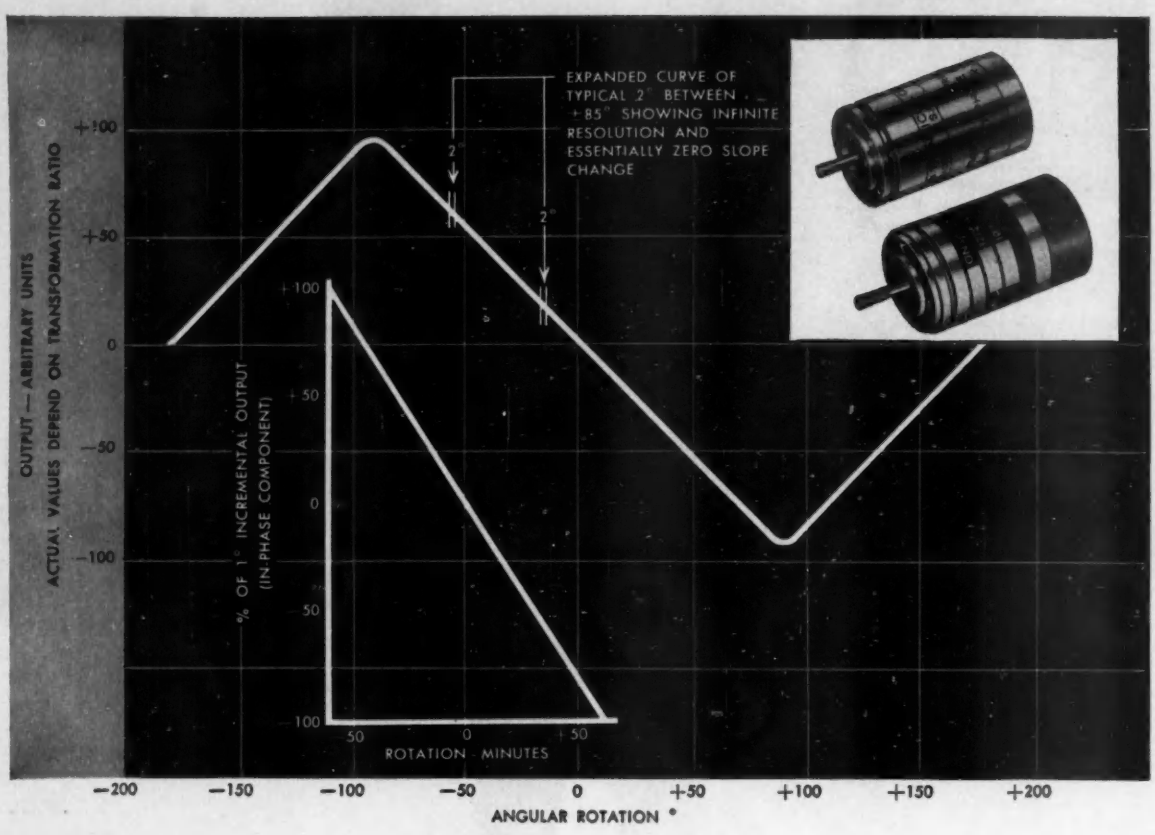
OTHER TI/IID PRODUCTS

- Complete Geophysical Instrumentation
- Measurement and Control Systems
- Automatic Test Equipment

CIRCLE 130 ON READER SERVICE CARD



Inductive pots give accurate noiseless output with infinite resolution

Weapons systems . . . analog computers . . . proportioning circuits—wherever the limitations of wirewound potentiometers can not be tolerated, these precision linear pots are the answer.

The Daystrom Transicoil Size 8 and 11 Inductive Pots provide extreme angular accuracy for applications requiring linear output and high gain amplification. There are no brushes wiping over turns of resistance wire to generate noise. Grounding problems are eliminated since each phase is electrically insulated from the other. When operated into the correct load, output is linear to within ±0.25% over the 170° (±85° from null) operating range. Output phase is dependent on direction of shaft displacement from null.

Write for complete specifications. Daystrom Transicoil, Division of Daystrom, Inc., Worcester, Montgomery County, Penna. Phone: JUNO 4-2421. In Canada: Daystrom, Ltd., 840 Caledonia Rd., Toronto 19, Ontario. Foreign: Daystrom International Division, 100 Empire Street, Newark 12, New Jersey.

TYPICAL CHARACTERISTICS

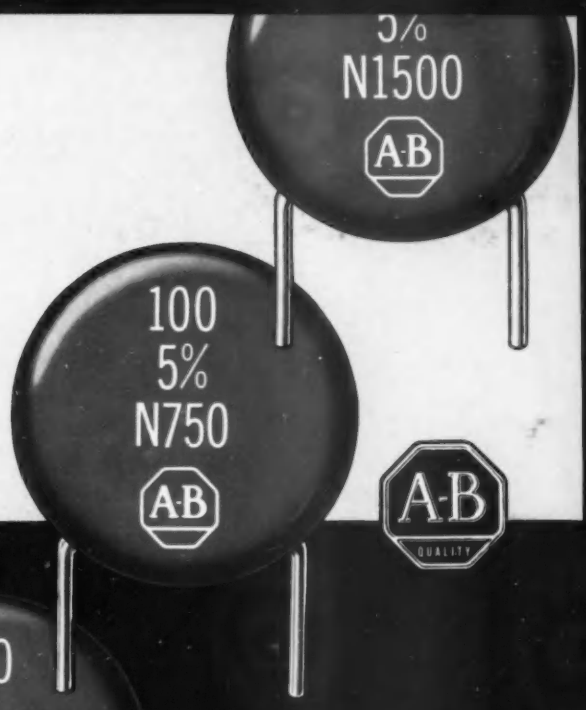
	Size 8		Size 11		
Volts	26	26	26	26	115
Excitation Power (watts)	.16	.16	.15	.15	.45
Excitation Current (ma)	27	27	30	30	24
Excitation Frequency (cps)	400	400	400	400	400
Sensitivity (v/°)	.107	.346	.107	.346	.620
Null Volts (mv)	7	20	7	20	40
Transformation Ratio	.350	1.130	.350	1.130	.452

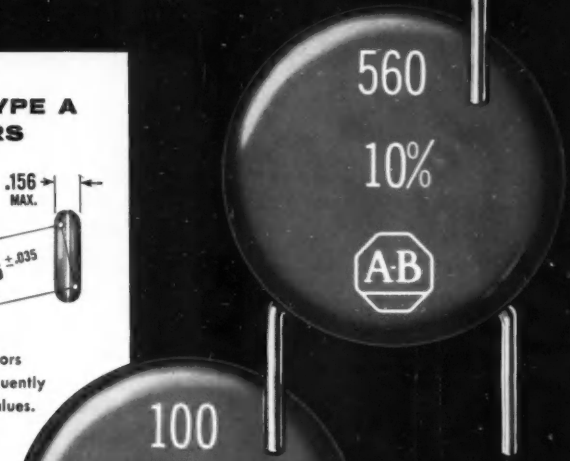
DAYSTROM TRANSICOIL DIVISION OF DAYSTROM, INC.

Representatives in Canada and Other Foreign Countries

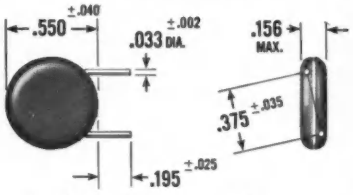
 CIRCLE 131 ON READER SERVICE CARD CIRCLE 132 ON READER-SERVICE CARD →

The beauty of this Capacitor is more than skin deep!





ACTUAL SIZE TYPE A CAPACITORS



Allen-Bradley Type A capacitors are available in the most frequently used types and capacitance values.

General Purpose Type in capacitance values from 10 mmf to .01 mmf.

Stable Type in capacitance values from 10 mmf to 0.1 mmf.

Temperature Compensating Type in characteristics from N4700 to P100, and in capacitance values from 10 mmf to 510 mmf.

Type A Capacitor . . .

One size for all values . . .

Designed for high speed assembly

Compare the attractive Allen-Bradley Type A ceramic capacitors with all the rest . . . you'll see instantly why more and more engineers are specifying them and will not accept substitutes —because there aren't any! The exclusive "Auto-Coat" process makes possible—for the first time—a capacitor of real beauty, precise physical uniformity, plus consistent and reliable quality and performance.

The smooth, tough insulating coating and the inherent mechanical uniformity of Type A capacitors permit easy hand or accurate automatic insertion on printed boards. Also, the "Auto-Coat" process prevents rundown on leads—costly wire cleaning and crimping to prevent soldering failures are unnecessary.

For full information on the *superior* physical and electrical properties of A-B Type A capacitors, send for Technical Bulletin 5401.

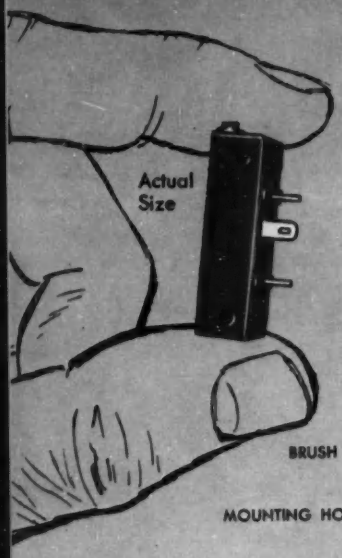
ALLEN-BRADLEY

MEMBER OF EIA

Quality Electronic Components

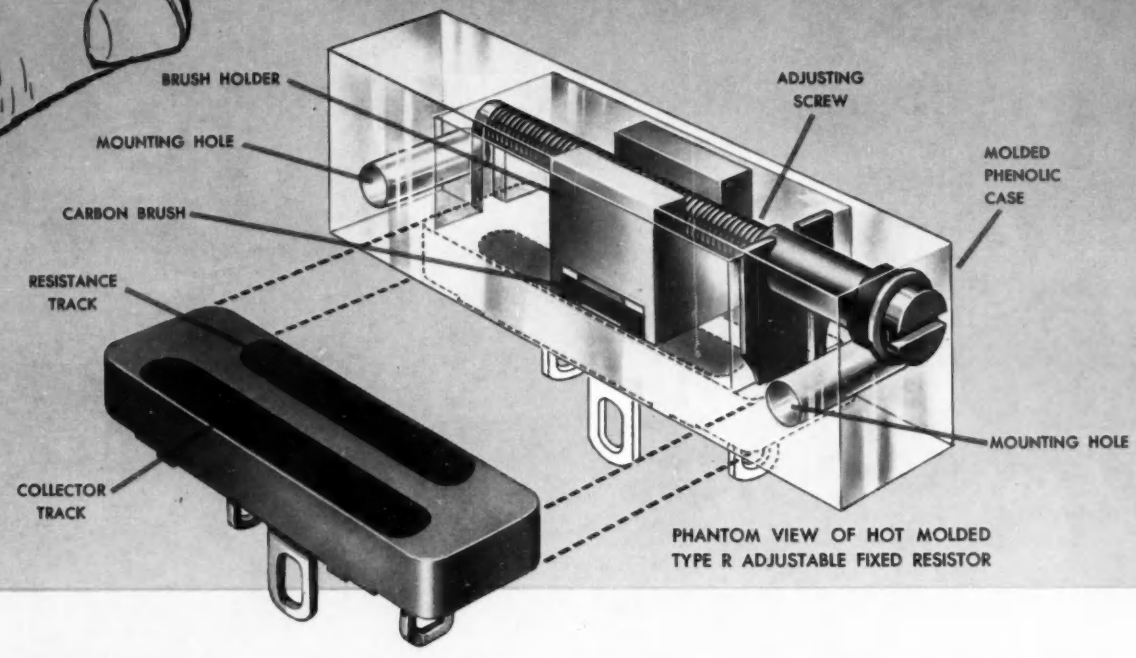
Allen-Bradley Co., 222 W. Greenfield Ave., Milwaukee 4, Wis.
In Canada: Allen-Bradley Canada Ltd., Galt, Ont.

4-59-E



NEW ALLEN-BRADLEY

Adjustable Fixed Resistor



PHANTOM VIEW OF HOT MOLDED TYPE R ADJUSTABLE FIXED RESISTOR

Exclusive hot molded dual track resistance element and carbon brush give unmatched reliability and long life

SPECIFICATIONS

Power Rating: ¼ watt at 70°C ambient
Voltage Rating: 350 volts maximum
Temperature Range: −55°C to 120°C
Resistance Range: total resistance values from 100 ohms to 2.5 megohms ±10% or ±20%
Adjustment: approximately 25 turns
Dimensions: approximately 1¼" x 21/64" x ¼"
Terminals: lug and pin type terminals on 0.1" grid system and are gold plated for ease of soldering.

Here's a new, compact, adjustable fixed resistor—the Type R—with Allen-Bradley's exclusive hot molded resistance element. It's the same type resistance element used in the popular Type J and Type G units . . . which have proved unequaled for reliability and long life. Operation is exceptionally smooth—no abrupt resistance changes occur with adjustment. The molded case of the Type R adjustable fixed resistor is watertight and dust-tight. The mounting for the moving element is self-locking to assure stable setting—and the entire unit can be "potted" after adjusting. The adjustment screw has a "free wheeling" clutch to prevent damage.

Send for complete information on this latest addition to the Allen-Bradley line of *quality* potentiometers.

Allen-Bradley Co., 222 W. Greenfield Ave., Milwaukee 4, Wis.
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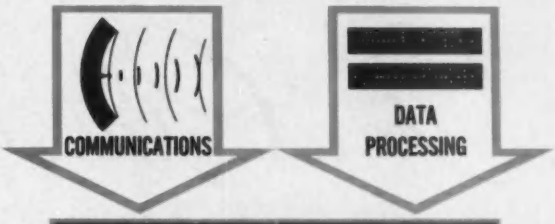
A-B QUALITY

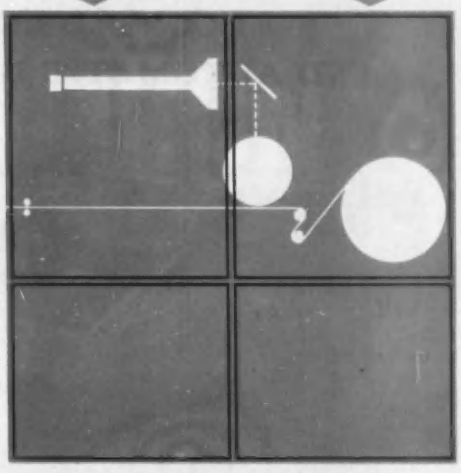
ALLEN-BRADLEY

QUALITY

ELECTRONIC COMPONENTS

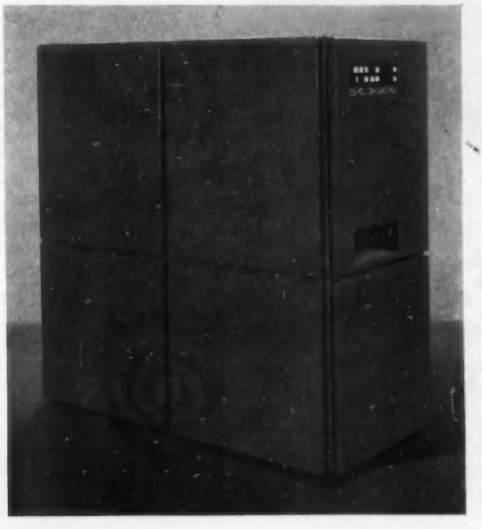
4-59-E





S-C 3000

MOST VERSATILE OF MEDIUM-SPEED ELECTRONIC PRINTERS



Printing ten to *10,000* words (500 lines) per minute, the S-C 3000 Medium-Speed Electronic Printer meets the demanding requirements of high-speed communications networks and data processing systems for reliable, economical printout equipment. The versatile S-C 3000 is compatible with most computers now in use and with such binary data links as telephone, telegraph and microwave. In addition to dry printing alphanumeric and symbolic data, the S-C 3000 is capable of facsimile reproduction. By combining the CHARACTRON® Shaped Beam Tube and the xerographic printing process, the S-C 3000 prints electronically on inexpensive, untreated paper — *without* impact, *without* troublesome, high-speed moving parts, *without* use of liquid developer — surpassing "high-speed" electromechanical printers in reliability, economy and simplicity of operation, yet printing at comparable speeds.

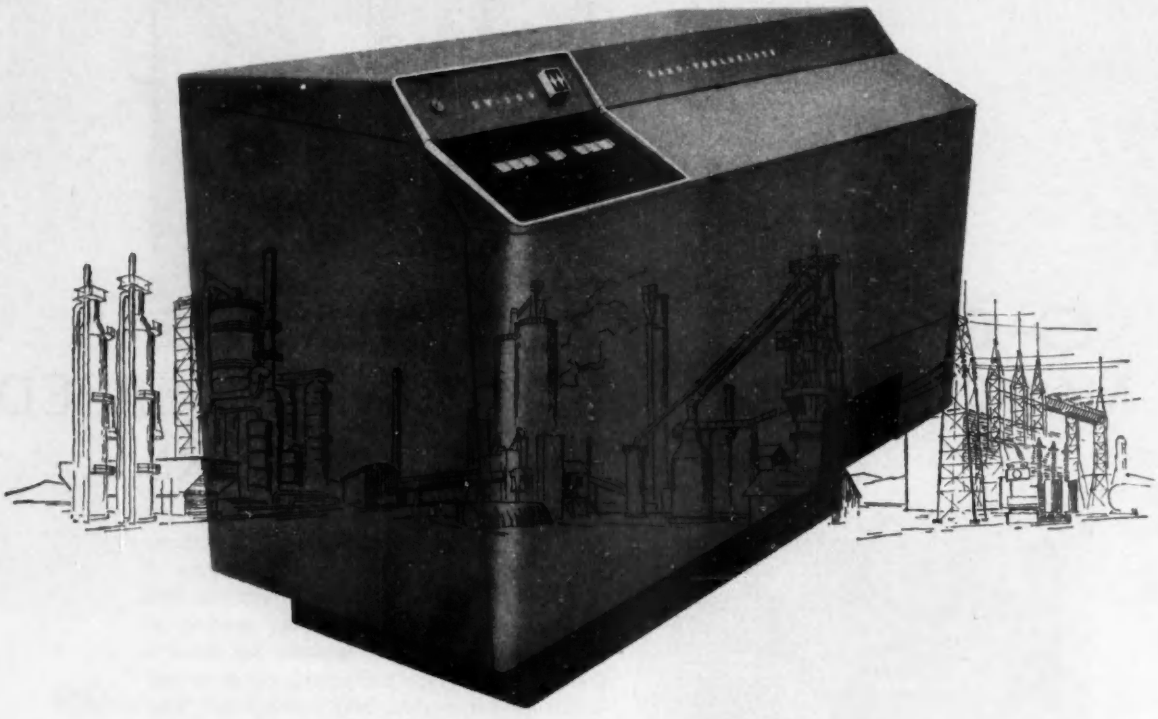
Send for complete information concerning S-C 3000 Medium-Speed Electronic Printers. Ask for Bulletin 9-C Write today: Stromberg-Carlson - San Diego, 1895 Hancock Street, San Diego 12, California.

STROMBERG-CARLSON
A DIVISION OF GENERAL DYNAMICS

CIRCLE 133 ON READER-SERVICE CARD

In a Class by Itself

FOR CLOSED-LOOP CONTROL AND AUTOMATIC DATA REDUCTION



The RW-300

DIGITAL CONTROL COMPUTER

OPERATING SYSTEMS incorporating the RW-300 for on-line control and data reduction are demonstrating these tangible benefits: *reduced costs, increased output, improved quality.*

HIGH RELIABILITY, inherent in the advanced design of the RW-300, is being proven by thousands of hours of dependable operation.

SYSTEMS ENGINEERING staff, experienced in the analysis of complex control and data reduction problems, is assisting industry with applications of the RW-300 in chemical, petroleum, steel, cement, electric power, and other fields.

NATION-WIDE SERVICE organization is providing skilled maintenance for this completely developed, production engineered, and thoroughly tested piece of *industrial* equipment.

For further information, call or write: Director of Marketing, The Thompson-Ramo-Wooldridge Products Company, P.O. Box 90067 Airport Station, Los Angeles 45, California, OSborne 5-4601.

THE THOMPSON-RAMO-WOOLDRIDGE PRODUCTS COMPANY

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NOW AVAILABLE IN TRANSITRON'S NEW PACKAGE

SILICON CONTROLLED RECTIFIER

handling 10KW power

TYPE	MINIMUM PEAK REVERSE VOLTAGE (Volts)	MINIMUM FORWARD BREAKDOWN VOLTAGE (Volts)	MAXIMUM AVERAGE FORWARD CURRENT (amps)	
			at T case = 100°C	at T case = 25°C
TCR 102	100	100	10	20
TCR 202	200	200	10	20
TCR 302	300	300	10	20
TCR 402	400	400	10	20

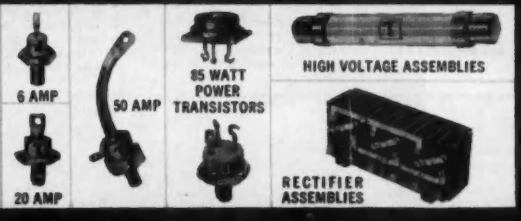
Maximum Storage Temperature Range — 65°C to +150°C
Maximum Operating Temperature Range — 65°C to +125°C
Send for Bulletin TE 1356

Transitron's Silicon Controlled Rectifier is a PNPN high power bistable controlled switching device. It is analogous to a thyratron or ignitron, with far smaller triggering requirements and microsecond switching. The low forward voltage drop permits high current ratings and provides high efficiency with low cooling requirements. The PNPN design permits higher voltage ratings and lower saturation resistance than power transistors. This permits the smallest packaging for high power control yet made possible.

Ratings currently available extend to 10 amperes at 100°C case temperature and up to 400 volts forward and inverse ratings. *Operation at 125°C is now permissible with derating.* Full ratings are possible at 35°C ambient with a 5" square heat sink. The peak control power is typically 1/200,000 of the output power!

Transitron's Silicon Controlled Rectifier has been designed into a new package for more rugged, convenient, and practical application. The 11/16" hex base and the general outline coincide with EIA standards for the 20-ampere rectifier.

OTHER TRANSITRON SILICON PRODUCTS FOR HIGH POWER USE



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electronic corporation
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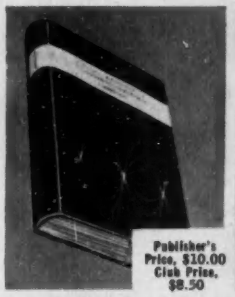
GIVEN TO YOU WITH A CHARTER MEMBERSHIP AND SENT WITH YOUR FIRST SELECTION

Values from $7.50 to $18.00



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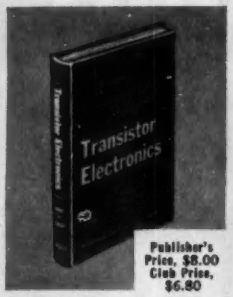
Basic Feedback Control System Design by C. J. Savant. Explains design and use of modern feedback control systems.



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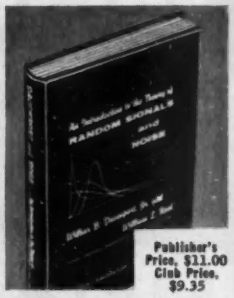
Transistor Electronics by D. DeWitt and A. L. Rossoff. Gives fundamentals and methods for effective transistor circuit design.



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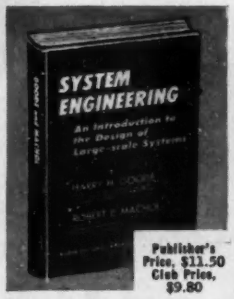
Random Signals and Noise by W. B. Davenport, Jr. and W. L. Root. Details theory for use in communication systems.



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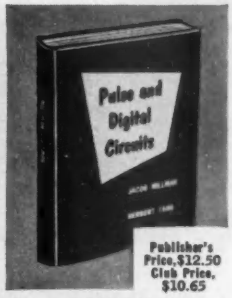

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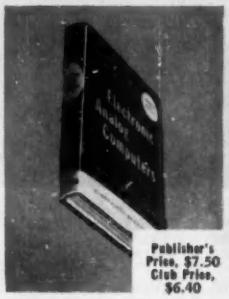
Pulse and Digital Circuits by J. Millman and H. Taub. Explains circuits for effective electronic system design.



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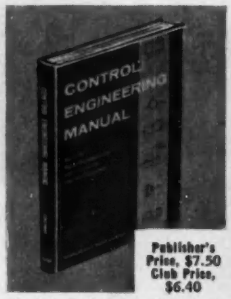

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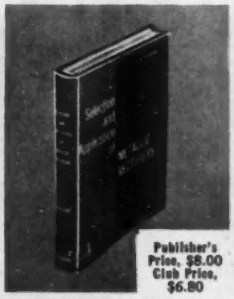
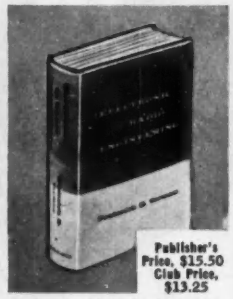
Control Engineering Manual edited by B. K. Ledgerwood. Step-by-step procedures in all aspects of control engineering and design.



Publisher's Price, $8.00 Club Price, $6.80

Selection and Application of Metallic Rectifiers by S. P. Jackson. Explains how to make best use of metallic rectifiers.



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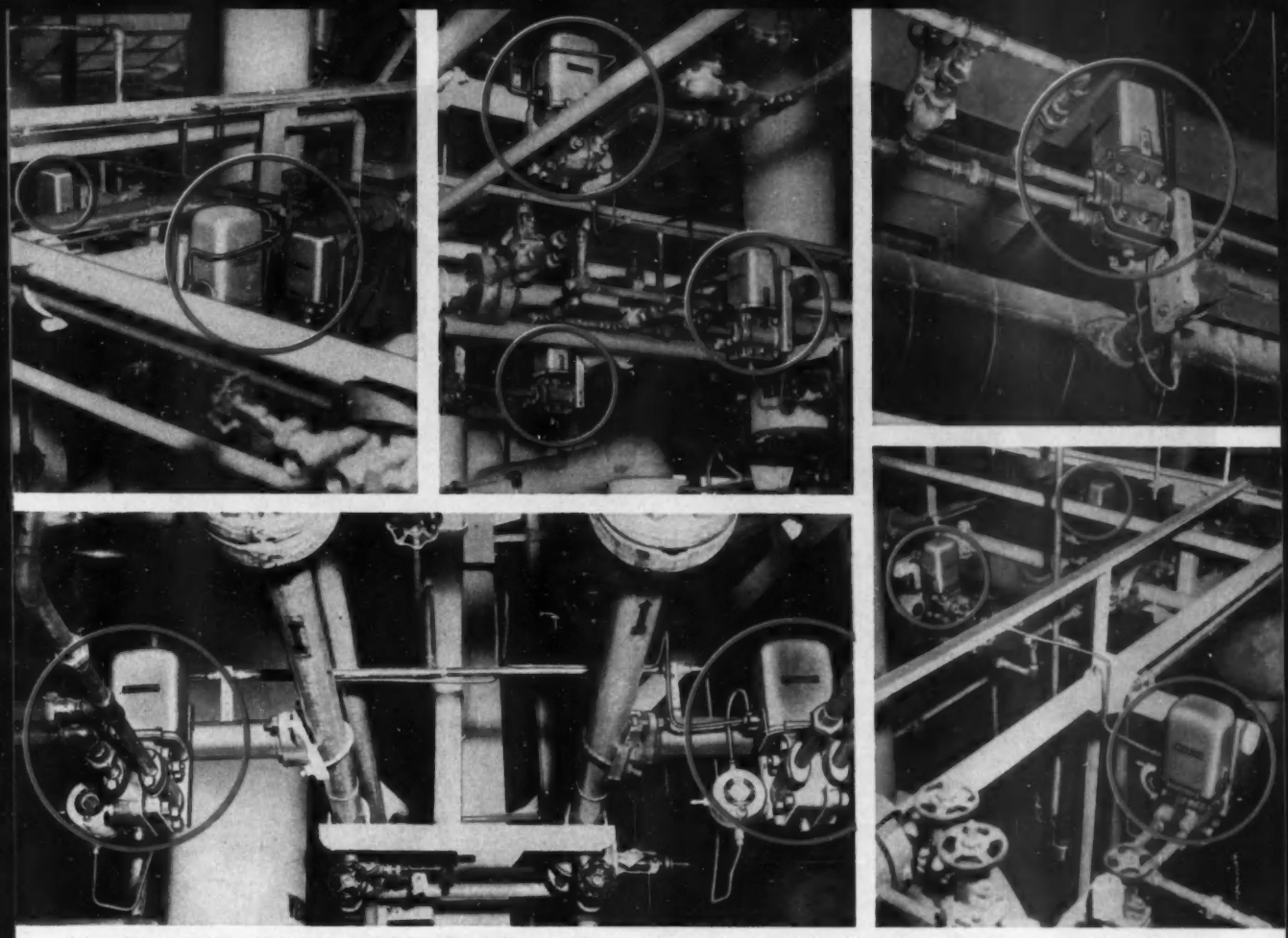
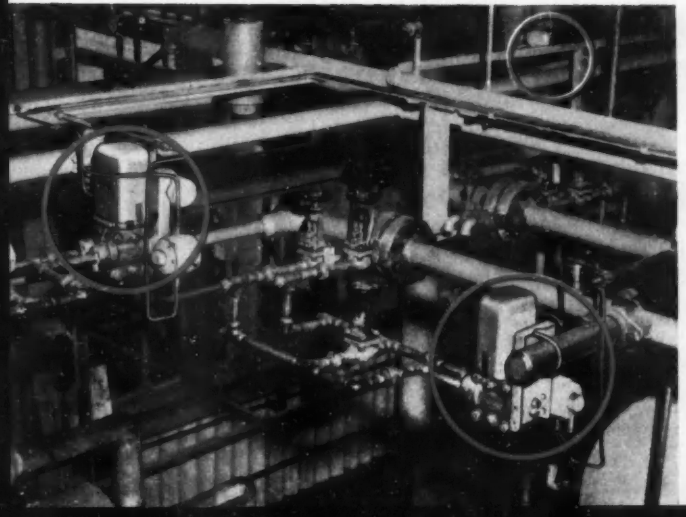


A few of the more than 100 Foxboro d/p Cell Flow Transmitters installed at Missouri Chemical Works of Hercules Powder Company, Louisiana, Missouri.

Hercules' Missouri Chemical Works reports:

"Foxboro d/p Cells* always accurate . . . never need re-calibration"



At Hercules Powder Company's 540-acre Missouri Chemical Works, there are over 100 Foxboro d/p Cell Transmitters in operation today — providing high-speed flow measurement and transmission throughout the ammonia, formaldehyde, methanol and pentaerythritol plants.

"Reliability is the big thing," according to Hercules instrument engineer J. J. VanShaik. "We can install a Foxboro d/p Cell and forget it. Once it's calibrated, we know it'll stay that way. We never even stock spare parts."

Hercules especially likes the Foxboro d/p Cell for flow control. "Gives us closer control," says instrument engineer H. McCombie. "Eliminates one possible source of inaccuracy and maintenance trouble in the control loop."

Let Hercules' experience be your experience — with Foxboro d/p Cell Transmitters as the basis for your control system. Write for full details in Bulletin 13-11A. **The Foxboro Company, 369 Norfolk Street, Foxboro, Massachusetts.**

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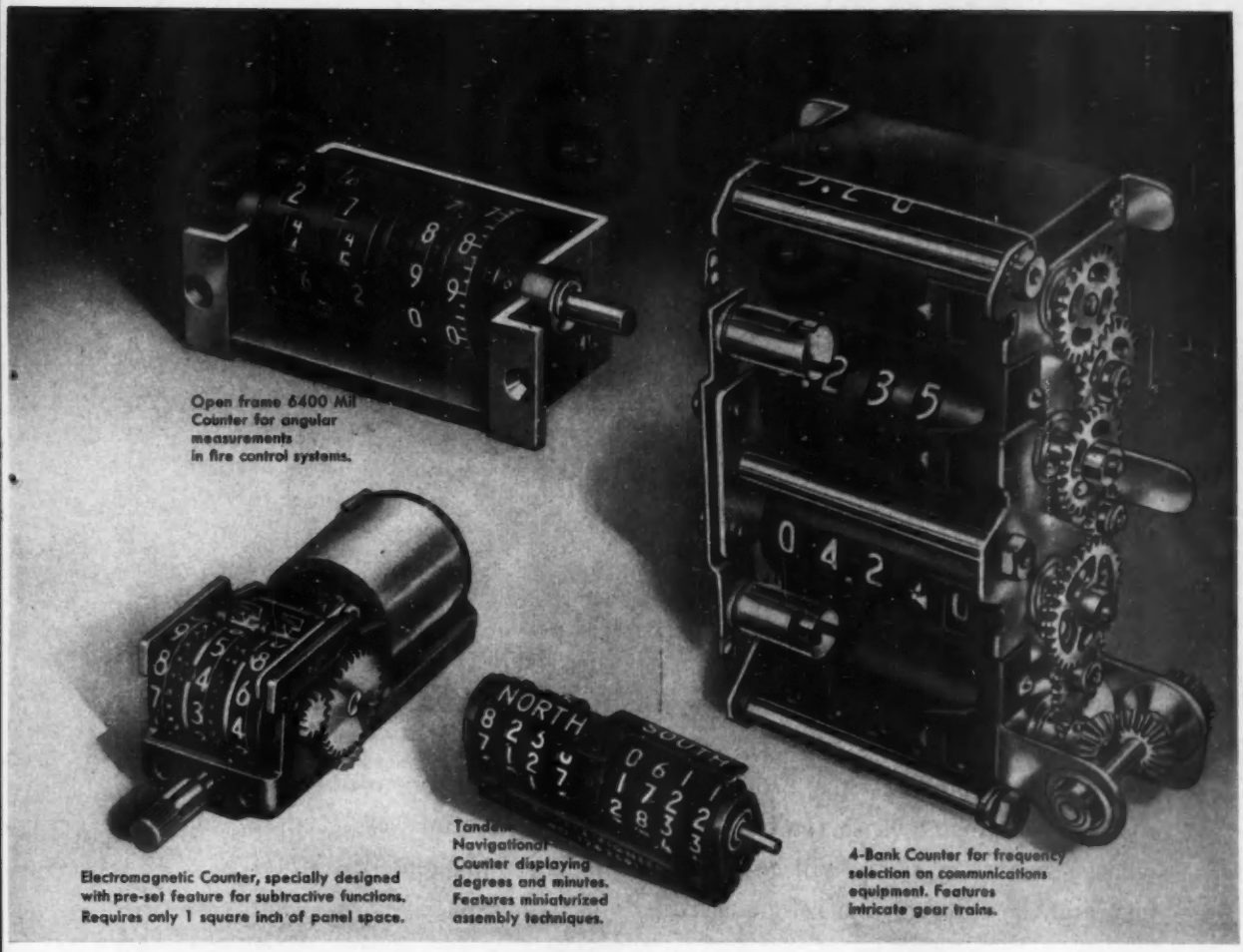
Make Instruments Do More With These Veeder-Root Counter Types: PREDETERMINED • ELECTRONIC • MAGNETIC


Open frame 6400 Mil Counter for angular measurements in fire control systems.
Electromagnetic Counter, specially designed with pre-set feature for subtractive functions. Requires only 1 square inch of panel space.
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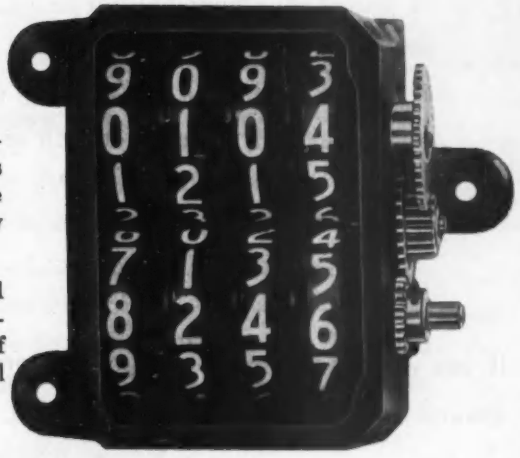
The Veeder-Root Counters shown here are only a small selection of the specialized line of precision counters developed for instrument and military applications. Each demonstrates Veeder-Root's ability to design and produce to high precision, fine tolerances, and military specifications, and to satisfy severe environmental testing requirements.

Send Us Your Requirements Now . . . Take full advantage of Veeder-Root's extensive Counter know-how to help improve the accuracy and reliability of your instrumentation or system. Contact your local Veeder-Root Counting Engineer or write direct.



Dual Counter device for communications equipment. Features intricate assembly and gearing.

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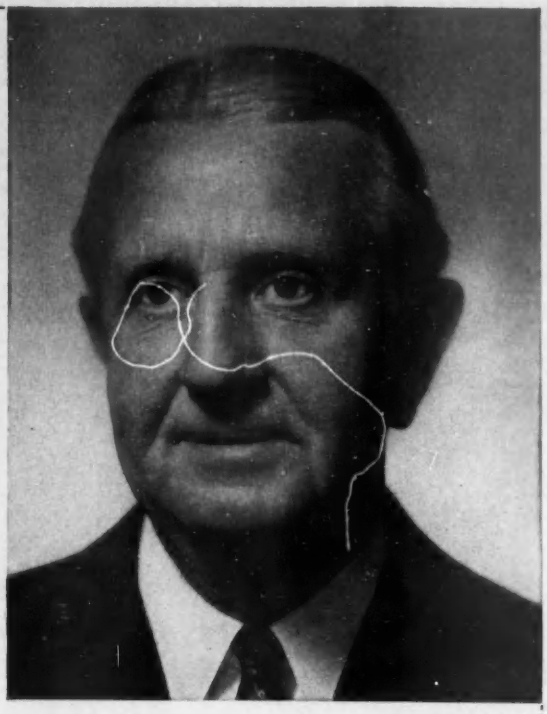

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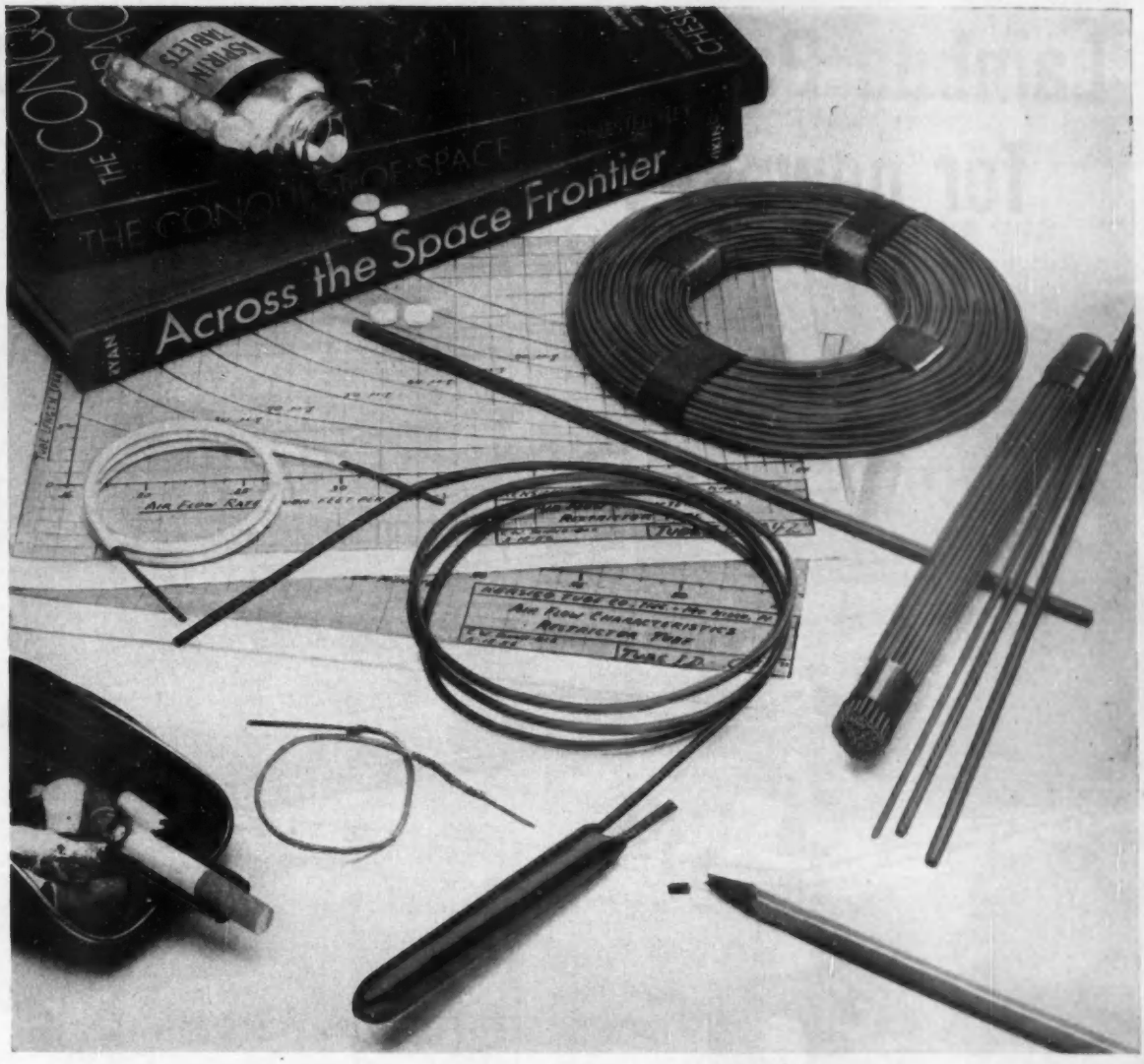

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No flaking. Exact specifications. Accurate flow testing. Overall tube cleanliness. Friendly service. Engineering consultation available. Write for Free Flow Charts today.

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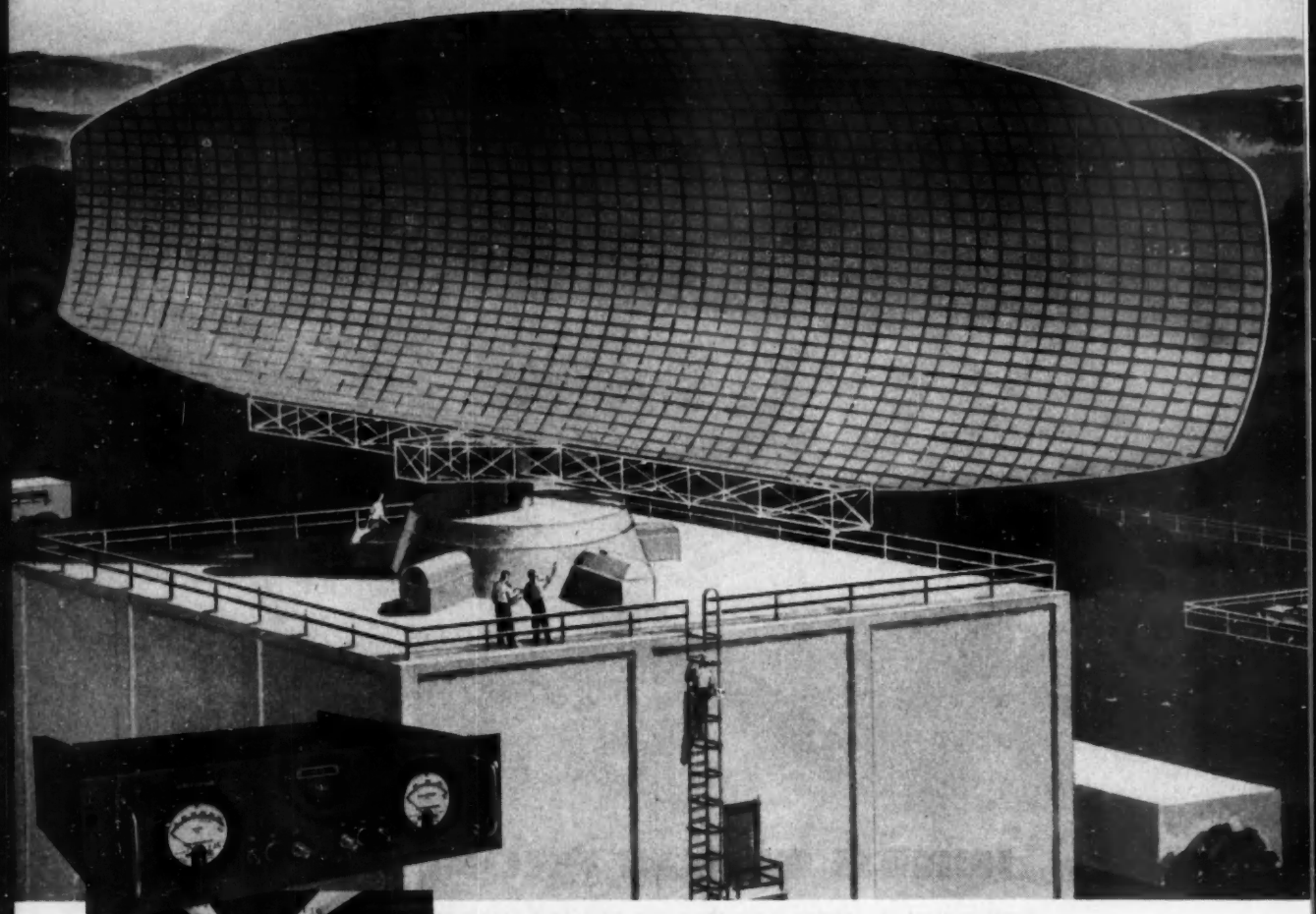
CIRCLE 138 ON READER-SERVICE CARD

Lambda Power Supplies specified for newest radar installation



"Off-the-shelf" Lambda power supplies —modified only with special panels, MIL meters and tubes—will be part of the complex radar equipment housed in the 85-foot tower at Thomasville, Alabama, one of four identical installations.

Meet MIL-E 4158 environmental test requirements

Sperry Gyroscope Co., operating under the technical guidance of the Rome (N.Y.) Air Development Center, is producing the new SAGE radar equipment (AN/FPS-35). The power supplies employed to power transmitters and receivers must be able to pass stringent tests.

Sperry's choice: Lambda's COM-PAK,® already widely used as a component in many rocket and missile programs.

All Lambda stock industrial power supplies are made to MIL quality and *guaranteed for five years.* They are pictured and described in a new 32-page catalog. Write for your copy.

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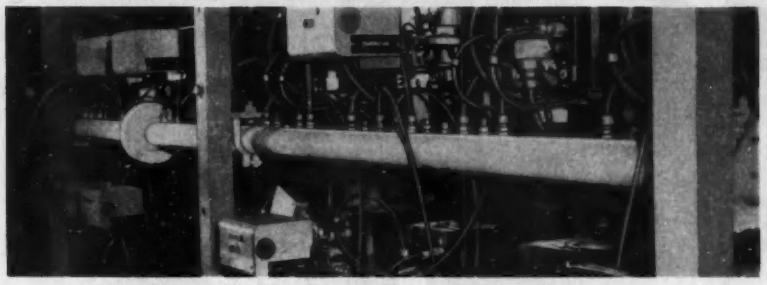
CIRCLE 123 ON READER-SERVICE CARD

IMPERIAL Engineering and Data File

ENGINEERED TUBE FITTINGS — VALVES — TUBING TOOLS



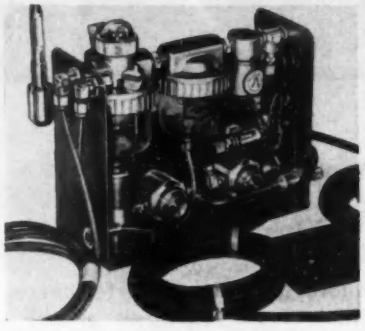
How Poly-Flo tube fittings cut installation costs, save space, eliminate bending

IMPERIAL'S Poly-Flo Fitting and Tubing now offer creative engineers a practical, low-cost solution to a wide range of tough jobs. The following case histories demonstrate typical Imperial product savings:

PROBLEM No. 1: High installation cost. Copper tubing cost $2.10 per ft. to install on an instrument panel for one Eastern Chemical plant. Further, chemical corrosion created high replacement costs.

SOLUTION No. 1: For an identical panel where polyethylene tubing and Poly-Flo Fittings were used, labor costs were slashed to 14½¢ a foot . . . a savings of 93%. Poly-Flo Tubing is also impervious to most chemicals, creating extra savings.

Sensational savings in time and labor — as with this documented example — are typical when you choose Poly-Flo. Remember, you need only a pocket knife to cut the tubing to exact length.

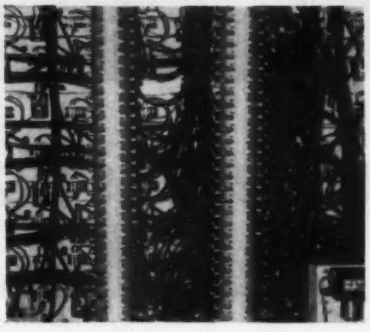


PROBLEM No. 2: Limited work space was encountered in assembling this dental equipment, designed by Aero Turbex. This equipment operates at speeds in excess of 250,000 rpm.

SOLUTION No. 2: Poly-Flo Tubing and Fittings beat this problem because no wrenches are needed for installation. Nut is just finger tightened, providing a connection that withstands the burst pressure of the Poly-Flo Tubing—from 250 to 600 psi.

Even in extremely close quarters **if you can reach the area with your fingers, you can make a foolproof connection.**

Tubing can be used in a temperature range from −90° to +175° F. Also, Poly-Flo is non-toxic, odorless and tasteless, an important consideration on food and medical equipment.



PROBLEM No. 3: Elimination of Tube Bending. Shown above is a Pressure Comparator Cabinet for an automatic data logging system. Because hundreds of tube bends were needed to complete the job, metal tubing costs were unduly high.

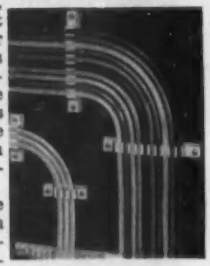
SOLUTION No. 3: Poly-Flo is so flexible, no time is wasted bending the tubing to fit. Tubing bends readily by hand. No special tools, either.

This tubing is ideal for smallest areas, too. For example, ¼" Poly-Flo tubing can be bent a full 360° to form a ⅞" radius circle *with no apparent constriction or collapsing of tube walls.*

Tubing is available in nine colors — color coding quickly identifies circuits. Sizes of tubing are: ¼" O.D., .040" wall; 5/16" O.D., .062" wall; ⅜" O.D., .062" wall; and ½" O.D., .062" wall.

Plastic Tube Rack Speeds Poly-Flo Tubing Installations

Holds from 1 to 10 plastic or metal tubes. Rack is especially convenient for holding bends in Polyethylene, Nylon and other plastic tubing. For use on panels, instrument boards and other installations where a number of tubes are involved. Cuts installation time — assures a neater appearance.



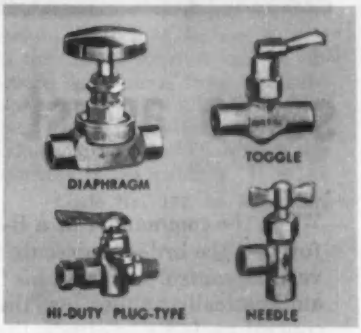
Rack can be cut quickly with a knife. Furnished in natural color Polyethylene.

Write for Engineering File No. 3025.

Fluid Control Valves for Every Application

Whenever you have an application calling for fluid control valves — check on Imperial's complete, quality line. Whether the job calls for needle valves, toggle valves, 2-, 3-, or 4-way plug valves or diaphragm valves, Imperial can provide the right valve to meet your requirements.

Write for Catalog No. 200.



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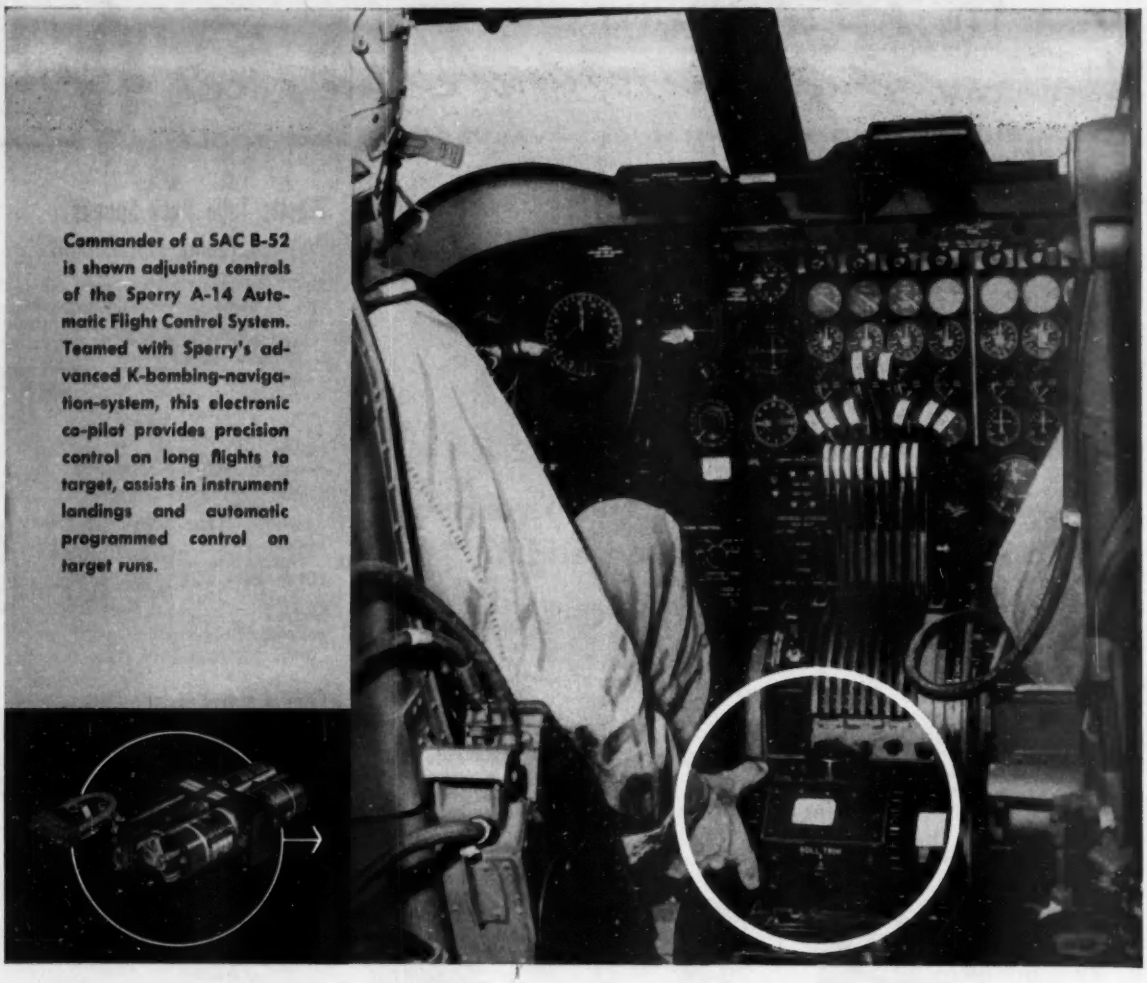

Commander of a SAC B-52 is shown adjusting controls of the Sperry A-14 Automatic Flight Control System. Teamed with Sperry's advanced K-bombing-navigation-system, this electronic co-pilot provides precision control on long flights to target, assists in instrument landings and automatic programmed control on target runs.

servo assist for sperry's electronic co-pilot

When the commander of a B-52 gives his Stratofortress the order to execute this or that maneuver, the control system of his "electronic co-pilot" automatically applies just the right force on the control surfaces to obtain the desired maneuver under the prevailing flight conditions. That's automatic flight control at its finest!

Daystrom Transicoil helps provide the calculated muscle for this flight system in the form of servo controlled pitch, roll, and yaw follow up; coordination integrator; and pitch integrator. Only the highest level of accuracy, performance, and reliability will do . . . for you, for us.

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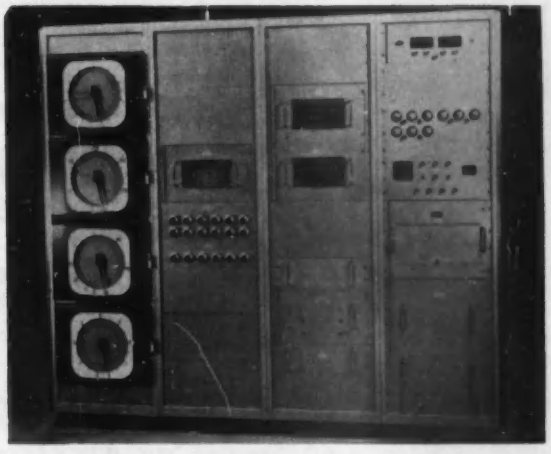
 CIRCLE 140 ON READER SERVICE CARD

NEW PRODUCTS

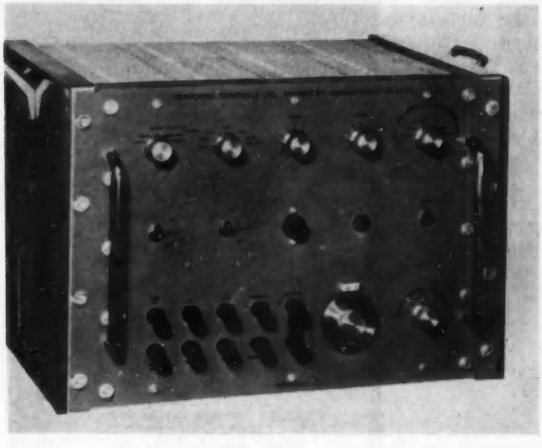
NEW LOGGER monitors test reactor



Designed and built for the Canadian Westinghouse Co., Ltd., this new recording system provides both typewritten and punched-tape records of variables measured during tests of a nuclear reactor. Temperatures, pressures, power levels, etc., can be measured and logged at a rate of 1 point per sec. The system permits complete flexibility of the data format in both the selection and sequencing of the variables recorded.

Newly designed input selectors connect the various input signals to appropriate indicators, and four shaft position encoders digitize the output of the indicator servos. A new input programmer, with a 102-point plugboard, eliminates the need for grouping inputs at the input selector terminal strip.—Datex Corp., Monrovia, Calif.

Circle No. 276 on reply card



FUNCTION GENERATOR speeds testing

This model LF-51 function generator can produce over 37 different waveforms suitable for servo tests, vibration studies, medical and geological research, analog computation, etc. Sine waves with frequencies from 500 cps to 0.0005 cps (one cycle every 33 min) may be generated with less than 1 percent total harmonic distortion. Ramps, triangular waves, sawtooth, and trapezoidal functions are available singly or repetitively. One-half or one complete cycle can be obtained and a prepulse may be used to start recording equipment so that initial response can be observed. Nonlinear functions are formed from triangular waves with a special shaping resistor controlled by a chain of biased diodes. Designed for rack mounting, the instrument consists of 16 modules plus a fully-stabilized power supply.—Marconi Instruments, Englewood, N. J.

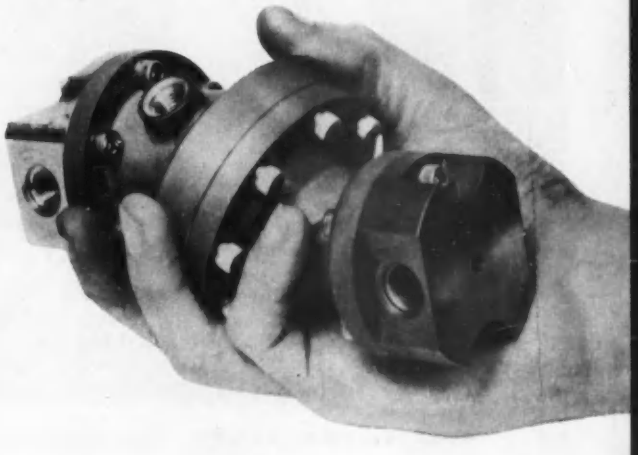
Circle No. 277 on reply card

HOT-GAS MOTORPUMP beats turbine

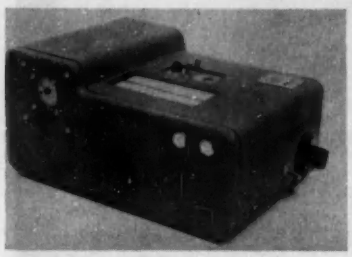
Photo shows the smallest in a new line of hot-gas motorpumps, designed to provide an auxiliary source of hydraulic power for missiles. This particular model can develop 8.9 hp yet weighs only 2.5 lb.

Units consist of an axial-piston type motor directly coupled to an axial-piston type pump. Special materials in the motor provide protection against the hot contaminated gas. Compared to a gas turbine, the axial-piston motor has a higher efficiency and operates at a lower speed. Power outputs range from 0.5 hp at 1,500 psi to 66 hp at 3,000 psi; speeds range from 18,200 rpm with a displacement of 0.095 cu in. per rev to 6,500 rpm with a displacement of 2.35 cu in. per rev.—Vickers, Inc., Detroit, Mich.

Circle No. 278 on reply card



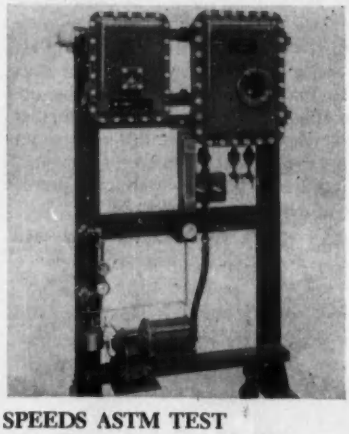
RESEARCH, TEST & DEVELOPMENT



DRIFT RECORDER

Designed to accept inputs from either a synchro control transformer or a potentiometer, this Model 420 Gyro Drift Recorder can be used to check gyros, stable platforms, and other devices requiring a long recording time constant. Periodic vibration, Scorsby motion, and similar cyclic inputs are rejected when recurring at or more than 1 cycle per min, regardless of their amplitudes.—Metrolog Corp., Pasadena, Calif.

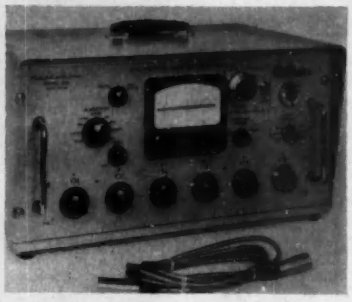
Circle No. 279 on reply card



SPEEDS ASTM TEST

The apparatus pictured above provides a means for assaying the boiling range of various petroleum fractions without the delays normally associated with such tests. It features a design response time of about 20 sec. A constant sample flow of 30 ml per min passes through a helical tube heat exchanger onto a flash evaporator where about 97 percent of the sample is evaporated. Temperature of the 3 percent residue is measured at the end of the evaporator tube. The residue then passes to a trap having a pointed outlet member. Drops falling from this point are sensed photoelectrically, and any change in residue flowrate produces an error signal that varies the evaporator input power. Thus, both sample and residue flowrates are constant, and the instrument records the temperature required to maintain this constant ratio.—Hallikainen Instruments, Berkeley, Calif.

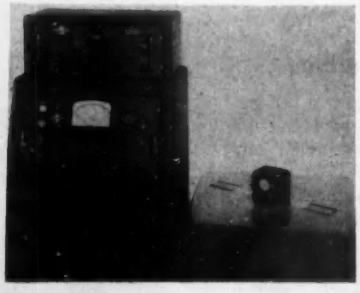
Circle No. 280 on reply card



HIGHEST RESOLUTION

Makers believe this new dc potentiometric voltmeter has the highest resolution capacity of any dc instrument now available for field use. Designed for a range of 0 to 10 vdc, the unit is accurate to within 0.025 per cent plus 3 μv. It has a readout facility of six decade switches with a resolution of 10 μv. The panel-mounted galvanometer extends this resolution to the sub-microvolt region. Stability of its reference supply is listed at 0.005 percent for line voltage variations between 107 and 127 vac.—The Siegler Corp., Anaheim, Calif.

Circle No. 281 on reply card



RATE TABLE

Photo above illustrates the Model 60A angular oscillating rate table for rapid frequency response testing of rate gyros and angular accelerometers. Featuring low distortion, the instru-

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1N68A	1N98A	1N118A
1N89	1N99A	1N126A*
1N90	1N100A	1N127A*
1N95	1N116A	1N128*
1N96		1N198

*JAN types

They're designed for long life and extreme reliability — and manufactured under Radio Receptor's unique gold bonding process which assures dependable high forward conductance without sacrificing desirable low reverse leakage.

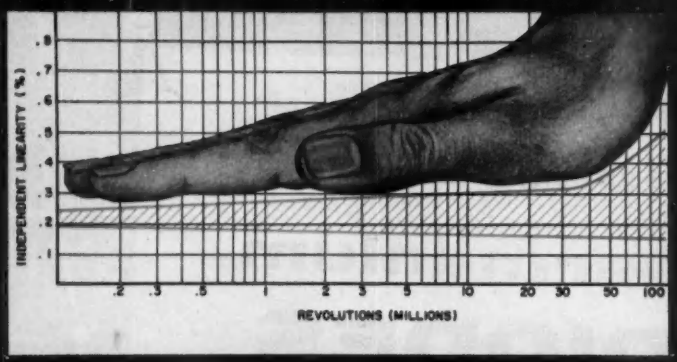
The listed diodes are only a fraction of the line. Radio Receptor DR types as developed by General Instrument Corporation have in most cases characteristics far in excess of any of the standard types. And all these germanium diodes are available in volume quantities for immediate delivery. Write us for full information.

Semiconductor Division

GENERAL INSTRUMENT CORPORATION
65 Gouverneur Street, Newark 4, N. J.

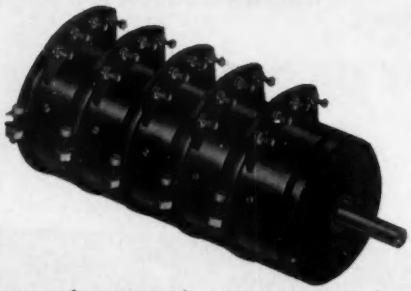
GENERAL INSTRUMENT CORPORATION INCLUDES F. W. SICKLES DIVISION, AUTOMATIC MANUFACTURING DIVISION, RADIO RECEPTOR COMPANY, INC. AND MICAMOLD ELECTRONICS MANUFACTURING CORPORATION (SUBSIDIARIES)

GENERAL INSTRUMENT DISTRIBUTORS: Baltimore: D & H Distributing Co. • Chicago: Merquip Co. • Cleveland: Pioneer Electronic Supply • Los Angeles: Valley Electronics Supply Co., Burbank • Milwaukee: Radio Parts Co., Inc. • New York City: Hudson Radio & Television Corp.; Sun Radio & Electronic Co. • Philadelphia: Herbach & Raderman, Inc. • San Diego: Shanks & Wright Inc. • San Francisco: Pacific Wholesale Co. • Seattle: Seattle Radio Supply • Tulsa, Okl: Capitol Electronics



only Markite Potentiometers...

Limit Linearity Changes for more than 50 Million Cycles



Where performance is paramount and critical applications demand the ultimate in reliability . . . Markite Potentiometers are specified.

The results of the quality control test charted above show why . . . linearity stability for more than 50 million cycles.

At Markite, achieving this high degree of reliability is nothing startling . . . it's normal . . . it's inherent . . . it's a product of Markite's program to surpass minimum requirements.

To complement reliable performance, Markite Conductive Plastic Potentiometers also provide:

- **Infinite resolution.**
- **Independent linearity to 0.05% in 1 1/16 in dia. units.**
- **Operation in ambient temperatures up to 200°C.**
- **Shock and acceleration resistance in excess of 100g.**
- **Vibration resistance in excess of 70g.**
- **Rotational speeds up to 1,000 rpm.**
- **Operation under all applicable Military Specifications.**

Write for Design Data and Catalog for Rotary and Rectilinear Potentiometers

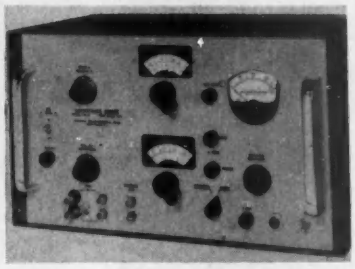
MARKITE **PRODUCTS CORPORATION**
155 Waverly Place • New York 14, N. Y.

CIRCLE 142 ON READER-SERVICE CARD

NEW PRODUCTS

ment covers the frequency range of from 0.1 to 150 cps, and will hold a constant sinusoidal rate as the frequency is changed. An auxiliary recorder console is available for plotting frequency response on an X-Y recorder.—Micro Gee Products, Inc., Culver City, Calif.

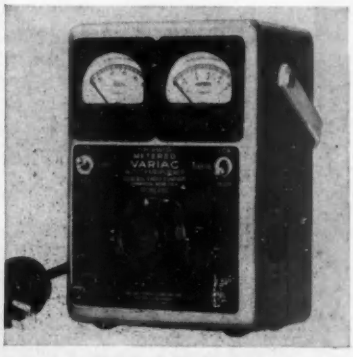
Circle No. 282 on reply card



CAPACITANCE BRIDGE

Designed for a 1-megacycle test frequency, the Model 75-A capacitance bridge covers a range of from 0.0002 to 1,000 $\mu\mu$f and contains a separate conductance balance with a measuring range of from 0.01 to 1,000 micromhos. Readability of differential capacitance measurements over 200 $\mu\mu$f is said to be within 1 ppm. Either direct or grounded capacitances can be measured. Design of the bridge permits connection of an external oscillator and detector for use with test frequencies below 100 kc.—Boonton Electronics Corp., Morris Plains, N. J.

Circle No. 283 on reply card



RUGGED PACKAGE

Rated at 5 amp, the Type W5MT3A Variac autotransformer features built-in meters for indicating both voltage and current in its output or load circuit. Shielding of these meters re-

F-106 model in Convair's supersonic wind tunnel at San Diego, California.

MicroSADIC...Consolidated's new all solid-state data processing system... is now in action sampling, digitizing, and recording at the maximum speed of computer input. In one high-speed wind tunnel, 25 force mode channels and associated block gaps are recorded by this integrated system in less than 20 milliseconds. In the pressure mode sampling of all 125 data channels requires only 0.8 seconds. These are just some of the capabilities of this flexible automatic system . . . a system that can also be custom-tailored to rocket test, thermostructure, or telemetry data reduction. Full information is in Bulletin CEC 3020-X3.

CONSOLIDATED SYSTEMS CORPORATION

1500 S. Shamrock, Monrovia, Calif. A SUBSIDIARY OF [illegible] DYNAMICS

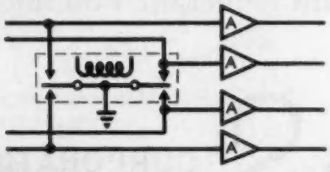
Complete from transducers through digital magnetic tape, the system acquires and processes data directly compatible with entry into either the IBM 650 or 704 computer. Automatic plotting of the computed data is also provided.

NEW

twin contact miniature DC-AC choppers

Eleven types, both single and double pole.
Long life.
Low noise level.
Extreme reliability.

DPDT
LOW COST
FULL ISOLATION



A

Write for Catalog 515-B

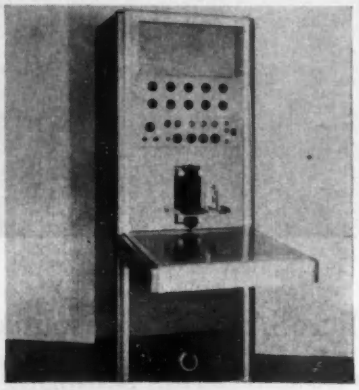
STEVENS INCORPORATED
ARNOLD
QUALITY SINCE 1943
7 ELKINS ST., SOUTH BOSTON 27, MASS.

CIRCLE 144 ON READER-SERVICE CARD

NEW PRODUCTS

duces the stray field and maintains accuracy of the instrument within 3 percent, full scale. A make-before-break range switch permits switching of the current meter range from 1 to 5 amp. Separate fuses protect the instrument when operating in either range. Outside case dimensions are 9⅛ by 6¾ by 6¾ in.—General Radio Co., West Concord, Mass.

Circle No. 284 on reply card



AUTOMATIC TESTING

Built to test computer modules such as printed logic circuitry, this new automatic tester contains its own power supplies, pulse generators, and voltage sources. As many as nine basic test programs may be performed on each circuit or module. These include tests of turn-on and turn-off characteristics, continuity tests, pulse response tests, etc. Up to 50 connections can be made to each module at any one time. Using all 50 connections and all 9 programs, 450 go/no-go test decisions may be performed without removing the module under test. Testing rates are adjustable from several tests per sec to several sec per test.—Atronic Products, Inc., Bala-Cynwyd, Pa.

Circle No. 285 on reply card

FORCE CALIBRATOR

A new portable force calibrator provides direct digital indication of pounds force, without requiring the use of correction charts. The standard unit, Model DFC-1, includes a 50,000-lb compression-type precision load cell in a separate carrying case. A four-digit readout scale displays force in 10-lb increments. Accuracy of the instrument is within 0.1 per-

CEC's 5-119 Recording Oscillograph . . .
First Practical Approach to a UNIVERSAL
Oscillograph . . . Now Available for
Use With DIRECT-PRINT Materials.

New recording versatility with 3 interchangeable magazines

With a new high-actinic light source and Slot-Exit Magazine, the 5-119 now becomes one of the most truly universal tools of data processing available. Addition of the direct-print process and new magazine to the 5-119 now brings you three uniquely different recording processes, enabling engineers to select the process best suited to specific test requirements.

PROCESS 1 DIRECT-PRINT... Clearly resolves writing speeds to 100,000 ips. High-actinic light source 5-119 P4-36V (or -50V) and new 5-051 Slot-Exit Magazine produce records on standard direct-print papers without chemical processing of any kind. Records emerge from the magazine slot continuously, and latensification takes place in ordinary room fluorescent light.

PROCESS 2 RAPID-ACCESS... Provides the shortest access time of any known process, and yields records of higher trace contrast and greater permanency than afforded by direct-print materials. Process employs the 5-036B DATARITE Magazine which automatically develops and dries oscillogram as quickly as data are recorded. Provides ready-to-read test results almost simultaneously with the occurrence of events under study.

PROCESS 3 CONVENTIONAL... Used where the finest available recording trace and contrast with highest writing speed are paramount requirements. Records are contained by the 5-006A Standard Magazine which uses conventional 12-inch films or papers. Records are processed following the record run.

The 5-119 provides 36 or 50 independent data input channels... Wide record-speed and frequency-ranges... Flash-Timing System to synchronize timing lines of 2 to 100 remote oscillographs. For complete details call your nearest CEC sales and service office, or write for Bulletin CEC 1536-X1.

Electro Mechanical Instrument Division CEC

CONSOLIDATED ELECTRODYNAMICS *300 No. Sierra Madre Villa, Pasadena, Calif.*

FOR EMPLOYMENT OPPORTUNITIES WITH THIS PROGRESSIVE COMPANY, WRITE DIRECTOR OF PERSONNEL

HEISE GAUGES

The Standard of the World

Heise Laboratories specialize in the manufacture of precision laboratory instruments for critical fluid pressure applications.

The Heise Gauge is a world recognized standard for pressure measurement used by many laboratories in place of the dead weight tester for reference data.

Heise Engineers are always available for advanced research and development. Prompt and skillful attention to inquiries in the precision pressure instrument field is a Heise tradition.

PRESSURE RANGES	DIAL SIZES	PRICES
15 to 50,000 P.S.I.	8½"-12"-16"	from $166.75

DELIVERY within 30 days

HEISE BOURDON TUBE COMPANY, INC.
BROOK ROAD, NEWTOWN, CONNECTICUT, U.S.A.

CIRCLE 146 ON READER-SERVICE CARD

NEW PRODUCTS

cent. Total weight of calibrator and cell is 24 lb.—Performance Measurements Co., Detroit, Mich.

Circle No. 286 on reply card

PLUS. . . .

(287) **Boonshaft & Fuchs, Inc.**, Huntingdon Valley, Pa., recently released data on a new **visual phase sensitive detector** for evaluating performance of ac servo systems. . . . (288) Manufactured by **Crest Instrument Div. of Magna Products, Inc.**, Santa Fe Springs, Calif., the Model L-2 **Corrosometer** automatically "tracks" corrosion as it occurs and plots this as a function of time. . . . (289) A portable, high-performance **gas chromatograph**, the Model 15 Chromat-O-Flex, is now being offered by **Loe Engineering Co.**, Pasadena, Calif.

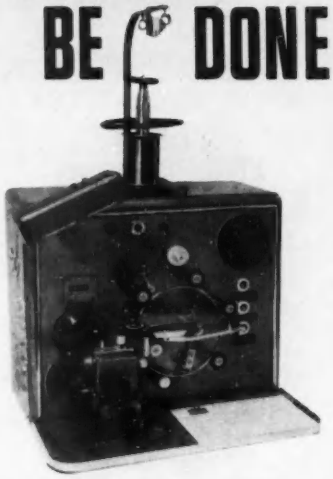
Circle No. 287, 288, or 289 on reply card

DATA HANDLING & DISPLAY

FOR PIPELINE DATA

This new digital readout console, part of a low-cost integrated pipeline information system, consists of a single analog-to-digital converter, a digital output control unit, and an automatic typewriter. Other elements of the overall system include: a pulse width telemeter receiver which gathers the analog signals from remote pressure, temperature, and flow transmitters; memories for storing these data; an optional alarm monitoring panel with adjustable high-low setpoints; and an input scanner which

THEY SAID IT COULDN'T BE DONE



BUT EDI DID IT

The EDI Model D-6 Toroidal Coil Winding Machine covers a range of core and wire sizes with any type of insulation which previously required two toroid winders. Now this one complete machine (THERE ARE NO ATTACHMENTS OR ACCESSORIES TO BUY) achieves a finished core range of 2" O.D. to ⅛" I.D. and a wire range of 24AWG to 46AWG, a tremendous saving in equipment cost to the toroid industry.

These accomplishments have been made possible by means of a unique method of winding-off the inside of the patented shuttle for one range of core and wire sizes, and off the top for another range.

In many instances, the Model D-6 will load and wind simultaneously from the reel through the shuttle to the toroid, a decided time saver.

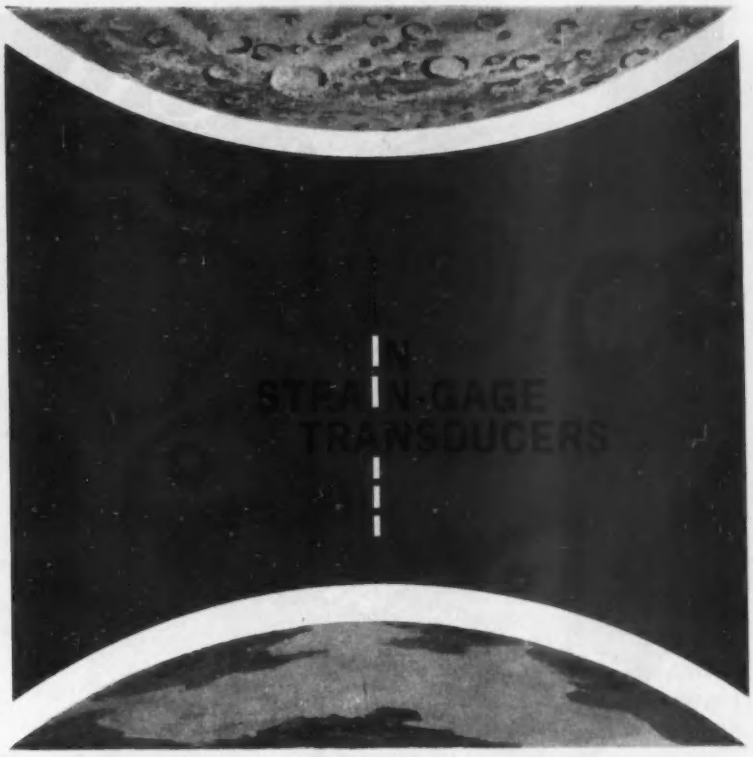
• Speed	0 – 600 turns per minute
• Wire sizes	24AWG — 46AWG
• Wire insulations	Formvar, Teflon, Cotton Covered, Enamel, and Litz.
• Wire types	Single and *multistranded*.
• Finished core sizes	2" O.D. to ⅛" I.D.
• Shuttle diameter	6" I.D.
• Shuttle sizes	⅛", 3/32", 1/16", 3/16" ¼" shuttle wire size #32 to 46AWG and multistrand
• Shuttle capacities	0 to one *mile*
• Core rotation	Automatic, 360° or any segment thereof, forward and reverse, precise winding control.
• Count	Positive electric count actuated by wire engaging a micro switch on each turn.

Height: 14½", Width 17¾", Depth 11".
Motor: ½ H.P. Universal Reversible.
Power: 115V-AC.

EDI electro devices, inc.

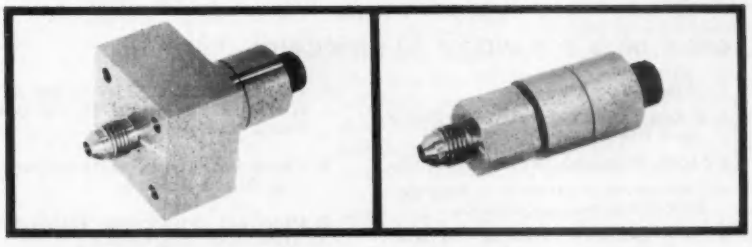
580 MAIN STREET, WILMINGTON, MASS.

CIRCLE 147 ON READER-SERVICE CARD



HIGH-TEMPERATURE PERFORMANCE TODAY

First with an operating 700°F pressure pickup, CEC is now extending high-temperature capabilities throughout its complete line of outstanding pressure pickups. Soon *all* pressure transducers will have the capability of continuous operation at 700°F. Now on the threshold of exciting new high-temperature developments, CEC is testing extended-range instruments for rocket- and jet-engine test stands, lunar probes, and space vehicles. Hundreds of CEC High-Temperature Pressure Pickups were used to test this country's first supersonic bomber... thousands will continue to perform in critical advanced projects. Your inquiry is invited... call your nearest CEC sales and service office or write for Bulletin 1308-X10.



Transducer Division **CEC**

CONSOLIDATED ELECTRODYNAMICS / 360 sierra madre villa, pasadena, california

FOR EMPLOYMENT OPPORTUNITIES WITH THIS PROGRESSIVE COMPANY, WRITE DIRECTOR OF PERSONNEL

CIRCLE 148 ON READER-SERVICE CARD

interchangeable with all standard JIC cylinders

With the introduction of the ALL NEW T-J Squair Head, Tomkins-Johnson now offers industry the most complete design range of air and hydraulic cylinders. Presently available in bore diameters from 1-½ to 8 inches, the T-J Squair Head is an interchangeable cylinder which produces maximum force and efficiency, with minimum pressures . . . and is also adaptable to the use of low pressure oil as the working medium. Write today to The Tomkins-Johnson Co., Jackson, Michigan, for Bulletin #SQ 10-58 and complete details.

CHECK THESE 10 POINTS OF T-J SUPERIORITY

1. One Piece Piston
2. Hard Chrome Cylinder Bore and Piston Rods
3. High Tensile Steel Tie-Rods
4. Cushion Adjusting Screw, Externally Adjustable
5. New Super-Cushion for air, or Self-Aligning Master Seal for oil (T-J Patents)
6. Solid Steel Heads and Mounting Plates Standard all Models
7. Port Design Allows Minimum Pressure Drop on Inlet or Outlet
8. Chevron Type, Self-Adjusting Rod Packing
9. Piloted Packing Gland—Absolute Alignment
10. Piston Rod, Extra Strong—Polished and Chrome Plated for Efficiency and Protection

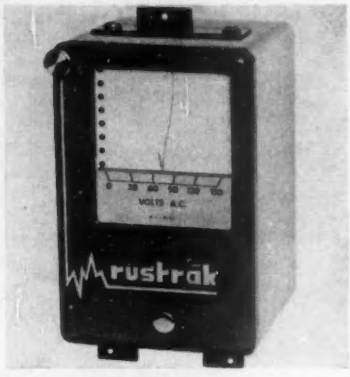
T-J TOMKINS-JOHNSON
RIVITORS · AIR AND HYDRAULIC CYLINDERS · CUTTERS · CLINCHORS

CIRCLE 149 ON READER-SERVICE CARD

NEW PRODUCTS

feeds the analog signals serially to the transistorized converter in the console. The typewriter logs the variables directly in psi, deg F or C, rpm, barrels per minute, or whatever unit of measurement is desired.—Fischer & Porter Co., Hatboro, Pa.

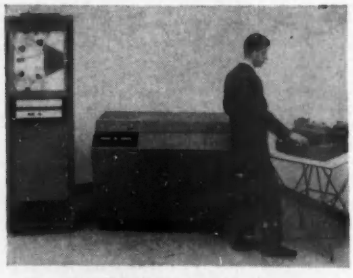
Circle No. 290 on reply card



TINY RECORDER

Manufacturer claims this new Rustrak strip chart recorder is the world's smallest and simplest. Available for 0-150 or 0-300 vac operation, it features inkless rectilinear recording free from distortion and houses a 62-ft roll of pressure-sensitive paper. Chart drives can be provided for speeds up to 30 in. per hr. Prices range from $69.50 to $83.95.—Rust Industrial Co., Manchester, N. H.

Circle No. 291 on reply card



TAPE UNIT FOR RW-300

Photo above shows a new magnetic tape unit (left) designed specifically for use with the RW-300 Digital Control Computer in on-line data collection and reduction systems. The tape unit consists of a magnetic core buffer and from one to eight magnetic tape transports. The buffer features control, parity-checking, and error-

KNOW YOUR SPEED

with the accurate
SERVO-TEK SPEED INDICATING SYSTEM

A truly versatile "package" provides accurate speed indication for almost anything that moves. Nearly every industrial process or machine can benefit by the economy and safety of continuous speed indication.

FEATURES

- **SELF-POWERED** No batteries or external power required.
- **LOW VOLTAGE** Connecting cable can be as long as 500 ft. for remote readings.
- **PERMANENTLY LUBRICATED BALL BEARINGS** Sealed against foreign particles and harmful vapors.
- **EASILY READ 4½" INDICATOR** Damped to withstand vibration and shock.
- **STANDARD RANGES** 0 to 100, 500, 1000, 2000, 3000, 4000, 6000, 8000, 10,000 and 12,000 RPM. These speeds can also be provided to read "Percent of Full Speed" or "Percent of Capacity."
- **STANDARD (SAE) AUTOMOTIVE AND AIRCRAFT MOUNTS,** as well as special scales, also available.

$87.00 includes generator, indicator (specify range), mounting base, coupling, and 15 ft. of electrical cable. Delivery from stock. Quantity discounts.

Servo-Tek
PRODUCTS CO
INCORPORATED

Main Office
1086 Goffle Road, Hawthorne, N. J.
Western Office
14736 Arminta Street, Van Nuys, Cal.

CIRCLE 150 ON READER-SERVICE CARD

14-channel magnetic tape recording system in LESS THAN TWO CUBIC FEET

DataTape's mobile recorder simultaneously records and monitors test data on 14 separate tape tracks in Direct, FM, and PDM modes. PCM (digital) data is handled with equal facility when the recorder is fitted with digital magnetic heads. Full IRIG range of tape speeds from 1⅞ to 60 ips is available. Rigid cast magnesium case with dust-proof cover assures unyielding precision in tape drive and tracking under severe environmental stresses. CEC all-metal-surface magnetic head stacks have track spacing, width, and nomenclature in accordance with IRIG specifications for perfect compatibility with other systems. Power supplies for the recorder are contained within the cast case.

New recording accuracy and portability with miniaturized electronics

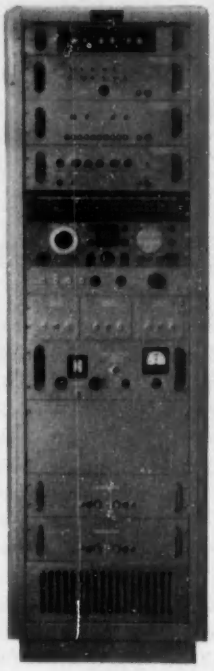
Plug-in miniaturized amplifiers are of modular design and are completely interchangeable regardless of mode selected. Wide range of input voltages (1 to 10 volts) and frequency response from d-c to 10 kc satisfy practically any data recording requirement. CEC's new FM amplifier provides ultra-linear, low-drift operation. FM center frequency is determined by precision internal plug-in units. Power supply and amplifiers are contained in extremely rugged but lightweight cast magnesium cases and do not require shock mounting. Complete 14-channel system, including recorder, weighs only 122 lbs. For complete information, call your nearby CEC sales and service office or write for Bulletins CEC 1578–X4 and 1592–X3.

DataTape Division **CEC**

CONSOLIDATED ELECTRODYNAMICS / 360 sierra madre villa, pasadena, california

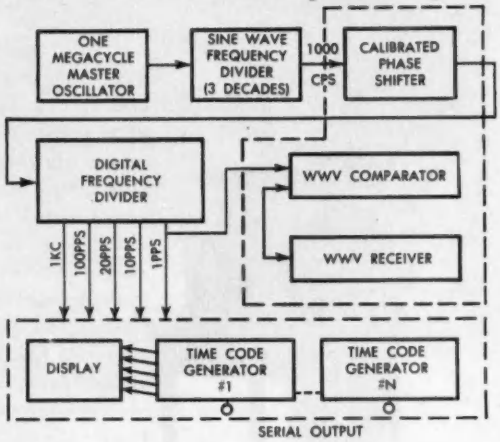
FOR EMPLOYMENT OPPORTUNITIES WITH THIS PROGRESSIVE COMPANY, WRITE DIRECTOR OF PERSONNEL

CIRCLE 151 ON READER-SERVICE CARD



Hermes Range Time Generator
Model 207

Missile Range TIMING SYSTEM *with Stability of* 5 Parts in 10^{10} per Day



This System is composed of a Precision Frequency Time Base Oscillator with a stability better than 5 parts in 10^{10} per day; a WWV Receiver with appropriate circuitry for synchronizing the System with WWV; Digital Timing Generators providing timing signals that can be recorded on magnetic tape, oscillographs, plotting boards, phototheodolites, etc.; and line driving equipments for time distribution.

The Hermes System is at present being used for range time generation at some of the country's major missile test ranges.

Write for Range Timing Bulletin PTS

FEATURES

- **TIME BASE FREQUENCY STABILITY** 5 parts in 10^{10} per day (max. drift of 22 μ sec.)
- **SYNCHRONIZATION** to WWV with transmission propagation compensation
- **TIME CODE FORMAT** Choice of any of the major time codes such as AFMTC, AFFTC, NOMTC, and others
- **OUTPUTS PROVIDED** for recording time on tape recorders, oscillographs, plotting boards, phototheodolites, etc.
- **TIME** is displayed in hours, minutes, and seconds through use of horizontally mounted Arabic indicators.
- **SINE WAVE FREQUENCIES** available at 1000 Kc, 100 Kc, 10 Kc, and 1 Kc, and pulse rates of 1000 pps, 100 pps, 10 pps, 1 pps, and 1 pp 15 sec.

WESCON SHOW
Booth Nos.
2821 and 2823

The new name for HYCON EASTERN, INC. is

Hermes Electronics Co.

75 Cambridge Parkway • Dept. J • Cambridge 42, Massachusetts

CIRCLE 152 ON READER-SERVICE CARD

NEW PRODUCTS

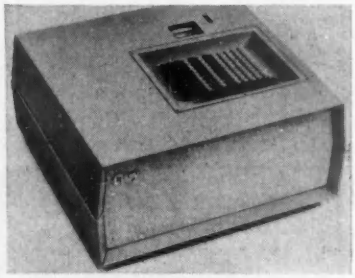
sensing circuitry, and the transports (modified version of the Ampex FR-400) feature read-write speeds of 75 in. per sec and rewind speeds of 160 in. per sec. Recording densities of 150 or 240 lines per in. are possible.—The Thompson-Ramo-Wooldridge Products Co., Los Angeles, Calif.

Circle No. 292 on reply card

DOCUMENT PRINTER

In a single operation, this Univac Solid-State document printer will compute, edit, punch, print on both sides, and segregate any standard tabulating-sized document. Its chief purpose is the preparation of final documents such as premium notices, utility bills, payroll checks, etc., directly from magnetic tape. At the Boston Edison Co., it is now being used for consumer billing and the establishment of a master card file on meters, meter readings, deposits, addresses, and accounts receivable. Cards can be processed at speeds up to 1,456 lines per min, with as many as 1,820 characters per card. A magnetic drum storage capacity of 50,000 digits permits a wide variety of programming control, editing, and computing operations.—Remington Rand Div. of Sperry Rand Corp., New York, N. Y.

Circle 293 on reply card



SCANNING PRINTER

Operating directly from logical levels, the Model 1961 scanning printer has

DIGITAL TIMING EQUIPMENT

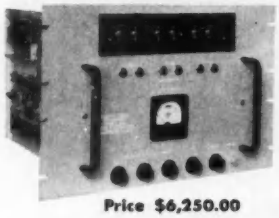
for all Recording Media in Data Acquisition and Reduction

During periods of data acquisition, Hermes companion units provide digital time indexing for simultaneous recording on magnetic tape transports, high- and low-speed oscillographs, strip chart recorders, plotting boards, data recording cameras, and others. Speeds of the different recording media can be selected independently of one another by adjusting the bit rate of the timing signal to conform with the speed of each data acquisition equipment.

During periods of data reduction, the Model 202 Magnetic Tape Search Unit is used for automatically controlling a tape transport to locate data on the basis of time indices previously recorded by any of the Hermes Timing Generators.

For Data Acquisition

DIGITAL TIMING GENERATOR, Model 201



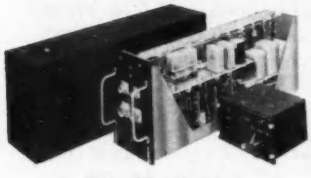
Price $6,250.00

generates binary coded decimal timing signals which are recorded on magnetic tape throughout the data recording periods, providing a precise digital index in terms of elapsed time. The Generator also visually displays the exact time in hours, minutes, and seconds as illuminated digits.

DIGITAL TIMING GENERATOR, Model 270

A solid state version of Model 201 **Price $7,950.00**

AIRBORNE DIGITAL TIMING GENERATOR, Model 206A



Price $7,450.00

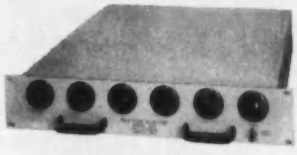
output is same as Model 201. This instrument designed specifically for airborne applications. Meets all essential requirements of MIL-E-5400 specifications.

RETARDED BIT RATE UNIT, Model 220

Price $3,985.00

operates in conjunction with Timing Generators, Models 201, 270, and 206A, for providing a pulse-height, pulse-width signal for recording time on equipments other than magnetic tape recorders.

RUN CODE SELECTOR, Model 225

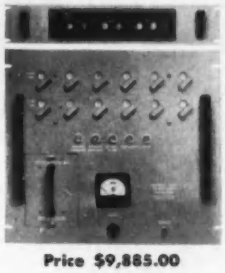


Price $2,500.00

is used with either Model 201 or Model 270 Timing Generator for inserting data run code numbers, or year, month, and day, in between timing words.

For Data Reduction

MAGNETIC TAPE SEARCH UNIT, Model 202



Price $9,885.00

is used to control a magnetic tape transport during periods of data reduction for automatically searching the tape on the basis of time indices previously recorded by any of the above Timing Generators. Model 220 Retarded Bit Rate Unit can also be used with Model 202 for reproducing time on Oscillographs as previously recorded on the tape.

TAPE INPUT PROGRAMMER, Model 230

Price $3,175.00

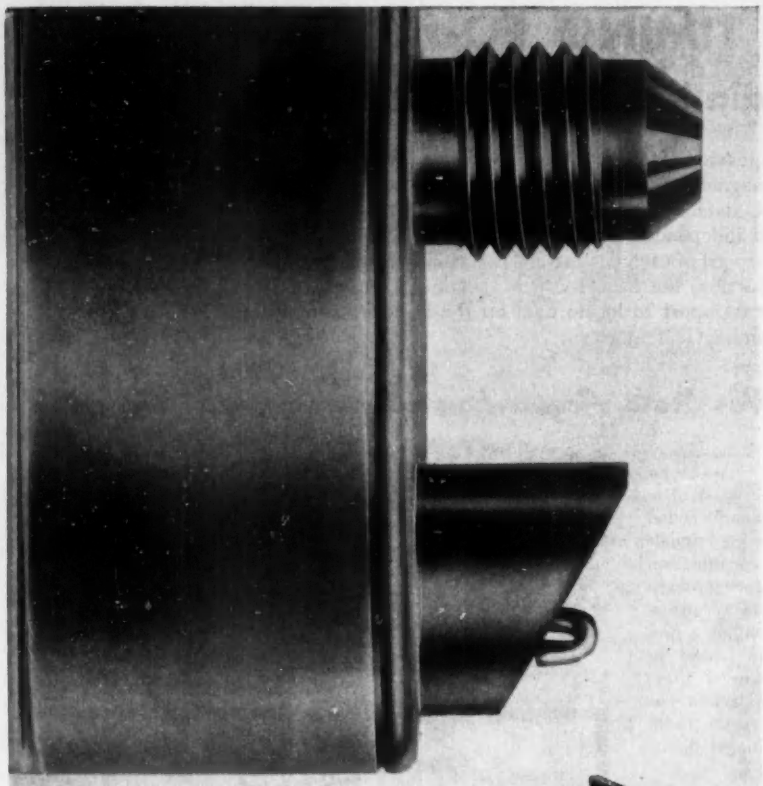
is used for automatically programming Model 202 Tape Search Unit in searching for several sequential start and stop times. The input to the Model 230 may be from any digital programming device such as a paper tape reader or computer.

Write for Technical Data for any of the above Equipment

The new name for HYCON EASTERN, INC. is

Hermes Electronics Co.

75 Cambridge Parkway • Dept. J • Cambridge 42, Massachusetts



new Bourns absolute pressure transducer

Miniature potentiometer transducer/ 35G vibration, 20-2000 cps/ High accuracy/5-ounce weight

New bourdon tube instrument for telemetering and control of missile, pneumatic, and hydraulic systems. Absolute, gage, or differential pressure ranges available with static error band of ±0.9%. Excellent noise-free low error performance in high vibration and acceleration environments.

Model	725
Pressure ranges	up to 0-5000 psia
Static error band*	±0.9%
Dynamic error band (includes ±35G to 2000 cps)	±1.8%
Discontinuities (noise)	None
Size (exclusive of fittings)	1-¾" D x ⅞"

*Includes friction, hysteresis, linearity, resolution, repeatability

Write for complete technical data

BOURNS Inc.
P.O. Box 2112 J, Riverside, Calif.
Field Engineering Offices:
L. I., New York, and Dallas, Texas

Pioneers in potentiometer transducers for position, pressure and acceleration.

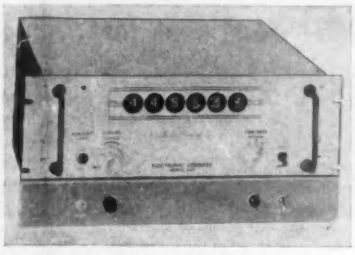
Exclusive manufacturers of Trimpot®, Trimit®

CIRCLE 154 ON READER-SERVICE CARD

NEW PRODUCTS

a 12-digit decoding and printing capacity for electronically controlled data from both decimal and binary coded decimal sources. These include digital voltmeters, shaft position transducers, electronic counters, step switch banks, relay banks, and selector switches. The printer's 12-column input keyboard provides for manual data entry.—Electronics Div., Clary Corp., San Gabriel, Calif.

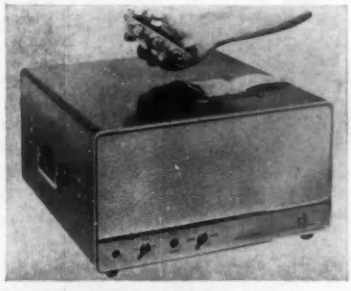
Circle No. 294 on reply card



INDICATING COUNTERS

Photo shows one of 10 different models in the 1300 Series of electronic tachometers and frequency counters. Nixie tubes provide an in-line readout that may be mounted on the front panel as shown here or remotely located. Available time bases include fixed selectable times, fixed special times, and preset variable times. Units will handle sine wave inputs of 5 to 150,000 cps, pulses from 0 to 150,000 per sec. Count accuracy is within 1 percent and display time adjustable from 0.1 to 10 sec.—I-L-S Instrument Div., The Meriam Instrument Co., Cleveland, Ohio.

Circle No. 295 on reply card



SOLID STATE PRINTER

Believed to be the first digital printer featuring solid state circuitry, this Model 400C-T is compatible with all makes of solid state counters having a 4-line 1-2-2-4 binary coded decimal output. Made to sell for less than

MINIATURE MANIFOLDS for Multi-Purpose CONTROL

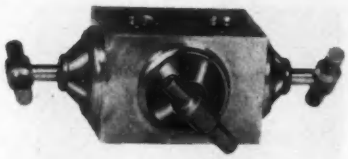


Photo ½ actual size

PACKLESS

"DEMI" M2 SERIES

All models of the standard Dahl "Demi" M2 series of three-valve manifolds are readily adaptable to clean liquid, gas and vapor applications. The size of these manifolds makes them especially suitable for pilot plant, aircraft and marine applications, flow control and automation. They are miniature in size, yet their patented form for bubble-tight shutoff makes them comparable to much larger valves in performance.

These manifolds consist of two block valves and one bypass valve in place of 3 separate valves . . . they eliminate two tees, four nipples and eight threaded connections. Models of the "Demi" M2 series come in a variety of barstock materials and may be ordered with special features such as: bolted bonnets, swaged-in TEFLON seats, toggle actuators, etc.

PRESSURE RATING Metal Body & Diaphragm Neoprene Diaphragm	 750 psi at 450°F 100 psi at 180°F
MAXIMUM Cv	0.4
CONNECTIONS	1/16", 1/8", 1/4" N.P.T.

Send for the "DEMI" Catalog D-1 and other technical data on Dahl pneumatic and hydraulic valves.

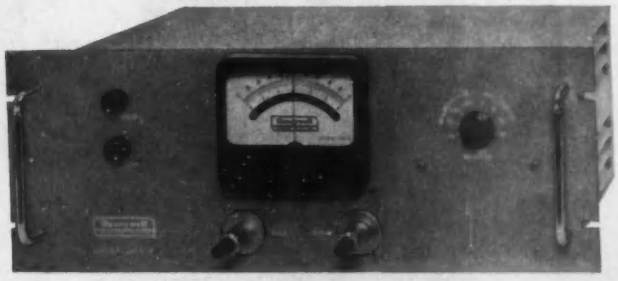
GEORGE W. DAHL COMPANY, INC.

86 TUPELO STREET, BRISTOL, RHODE ISLAND

CIRCLE 155 ON READER-SERVICE CARD

New General Purpose Amplifier

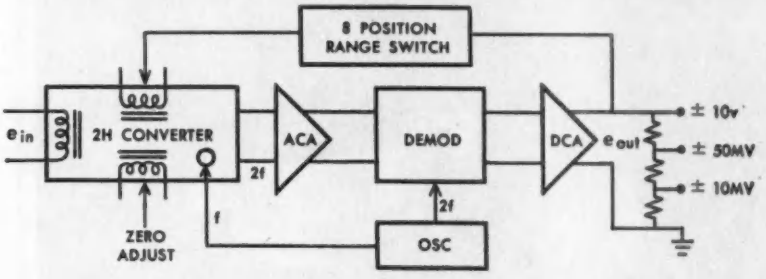
3 INSTRUMENTS IN 1



Model 2HLA-9 measures 19" wide x 7" high x 14" deep

The new Honeywell Differential Input Indicating Amplifier, Model 2HLA-9, is a general purpose, low level d-c instrument. It may be used as an ultra-sensistive null indicator, an indicating amplifier or a pre-amplifier for self-balancing recording potentiometers. Reliability, simplicity, ruggedness, plus sensitivity permit use of the Model 2HLA-9 in virtually every location where a source of 115 volts, 50 or 60 cps is available. The unit may be conveniently mounted on rack or bench.

The Model 2HLA-9 is a magnetic-electronic instrument that possesses the most desirable characteristics of both mechanical and electronic galvanometers, including high resistance to strays, overload protection and rapid response. Write for Technical Bulletin B-C2HLA-9 to Minneapolis-Honeywell, Boston Division, Dept. 34, 40 Life Street, Boston, Mass.



FEATURES

INPUTS: ±10, 30, 100, 300, 1000, 3000, 10,000, 30,000 μ volts.

ISOLATED DIFFERENTIAL INPUT: For operation at high a-c and d-c voltage above ground without error.

MAGNETIC CONVERTER INPUT: For accurate d-c to a-c conversion with minimum zero drift and high immunity to a-c ripple.

ADJUSTABLE ZERO SUPPRESSION: ±100% on 10 through 3000 μv ranges.

DRIFT: ±0.50 μ volt short term.

COMMON-MODE REJECTION: $10 \times 10^4/1$ or better at d-c, better than 250,000 to 1 at 60 cps.

OUTPUT: ±10 volts, ±50 mv and ±10 mv taps.

OUTPUT IMPEDANCE: 1000 ohms.

INPUT IMPEDANCE: Approx. 1000 ohms.

NOISE: Less than 0.1% rms 0-10 KC.

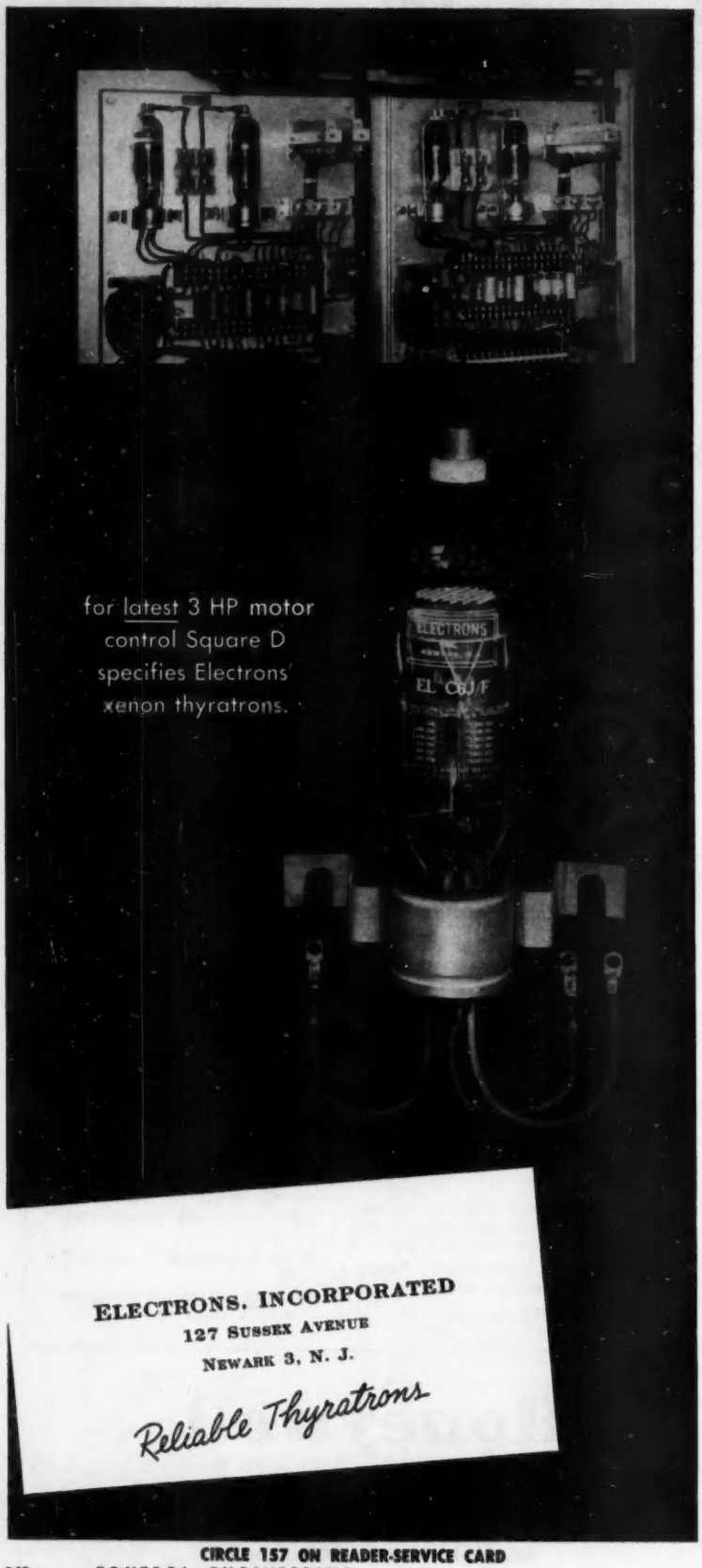
FREQUENCY RESPONSE: 3 db down at 5 cps maximum.

Honeywell

ISA SHOW
Booth Nos. 404, 408, 503 & 507

First in Control

CIRCLE 156 ON READER-SERVICE CARD

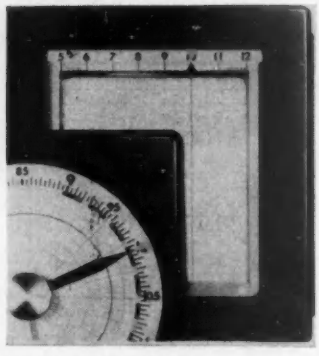


CIRCLE 157 ON READER-SERVICE CARD

NEW PRODUCTS

$1,400, it uses transistorized plug-in drivers for each digit. These may be changed around to match the outputs of other transistorized equipment. Other features include: standard 6-digit printout at the rate of 4 lines per sec; parallel input; and a code line input requirement of only 6 volts.—Computer-measurements Co., North Hollywood, Calif.

Circle No. 296 on reply card



COMPACT DESIGN

Pictured are two new space-saving models recently added to L&N's line of Speedomax-H Recording Controllers. Cases of both models are only 12 in. high and 11 in wide. The strip chart model has a 6½-in. linear scale and is best suited for detailed records, while the circular chart model is recommended for bold indication.

Characteristics:

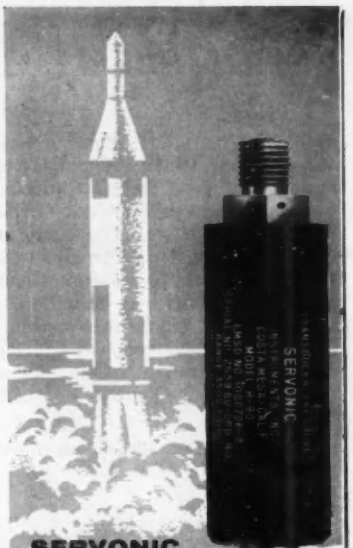
Range: 500 to 1,200 deg F
Accuracy: within 0.3 percent
Sensitivity: better than 0.1 percent
—Leeds & Northrup Co., Philadelphia, Pa.

Circle No. 297 on reply card

PRIMARY ELEMENTS & TRANSDUCERS

"HOT-SPOT" DETECTOR

Originally designed for fire and overheat protection in jet engines, the Fenwal "Line" detectors have now been modified for general industrial use. These devices are actually long lengths of a very flexible coaxial cable. Cable consists of a nickel wire center conductor, separated from an Inconel



SERVONIC

H-90

TRANSDUCER

Tiny, Rugged
Extremely Accurate
In Severe Environments

An important role in the current series of advanced *Polaris* flight testing is being played by Servonic's rugged, H-90 High Pressure Tranducers. Operating in the actuator equipment, the tiny potentiometer-type transducer monitors the pressure in the hydraulic system and reports the degree of pressure change. This information is relayed during ground checkout of the test vehicle and is telemetered to ground recording stations during test flights.

According to Lockheed Missiles and Space Division engineers the H-90 was selected because of its exceptionally small size, light weight and ability to perform accurately in severe missile environments. Critical elements of the H-90 are completely isolated and sealed-in-oil within a rugged alloy case to assure long life.

H-90 SPECIFICS

Range	0-3500 psig
Weight	5 ounces
Size	1" x 2¼"
Linearity	±0.5%
Hysteresis	1%
Vibration	to 20 g's
Temperature Range	−65°F to 275°

Servonic Pressure Transducers are available in a wide range of standard and special design for airborne, ground-support and industrial applications. Write for information.

SERVONIC
INSTRUMENTS, INC.
640 Terminal Way
Costa Mesa, California

CIRCLE NO. 158 READER SERVICE CARD

WHEN YOU HAVE
extraneous common mode signals

AND WANT TO MEASURE
0.1 to 100 millivolts full scale

ISA SHOW
Booth Nos.
404
408
503
507

AND THEN AMPLIFY

CHOOSE THE NEW HONEYWELL D-C AMPLIFIER

AccuData II

wide-band differential all-transistor D-C Amplifier for strain gages and thermocouples

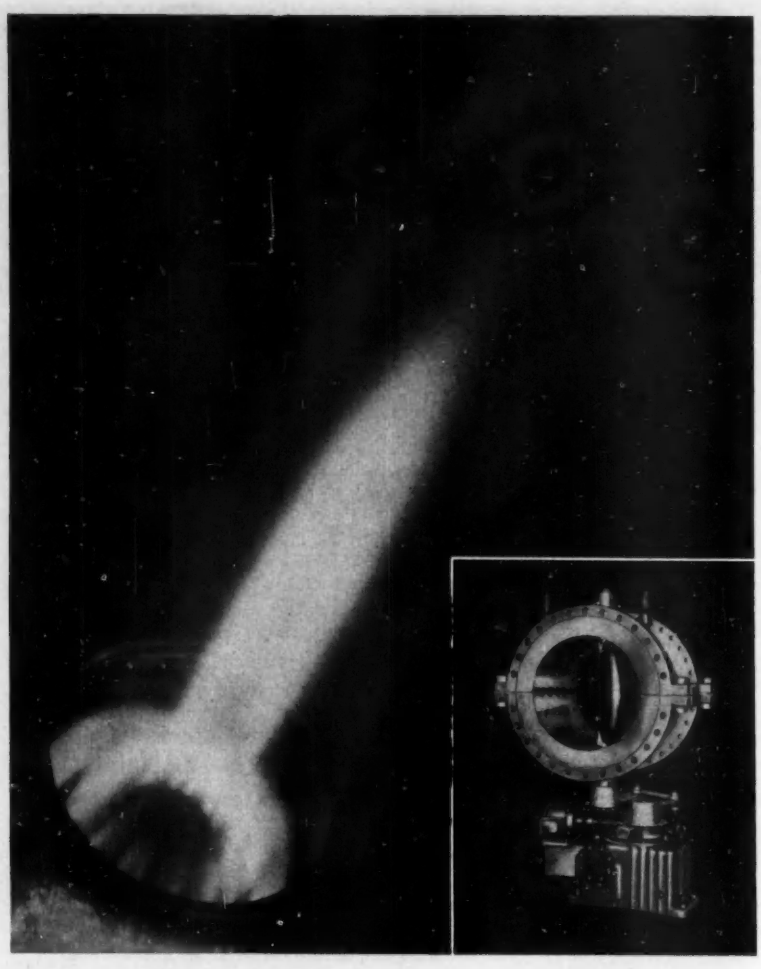
- **Full Scale Input:** Unbalanced: ±100 μv to ±100 mv Differential: ±3 mv to ±100 mv Open Loop: Below drift level
- **Full Scale Output:** ±2v at 50 ma, dc to 10 kc
- **Frequency Response:** to 20 kc
- **Output Impedance:** Less than 0.5 ohm at dc on all ranges
- **Input Impedance:** Unbalanced 3 to 100 mv ranges; greater than 20 megohms in parallel with 350 micromicrofarads. Differential: Greater than ± 2 megohms
- **Equivalent D-C Input Drift:** Less than 2 μv/10°F ambient temp. change on 0.1 to 30 mv input ranges
- **Equivalent Input Noise:** 4μv peak-to-peak on 100 μv to 300 μv range (0-10 cps). 8μv rms on 10 to 30 mv ranges (0 to 100 kc)
- **Common Mode Rejection:** 200,000 at 60 cps on 3 to 30mv ranges

The new Honeywell AccuData II is a completely transistorized D-C Amplifier designed for use in high accuracy data handling systems as a wide-band pre-amplifier for strain gages and thermocouples. Its output can be fed to electronic or electromechanical analog-to-digital converters and simultaneously recorded on galvanometer oscillographs or magnetic tape. Either differential or single-ended input modes can be selected by an eleven position range switch. This switch changes the gain in three-to-one steps. Intermediate gains with high resolution are provided by a ten-turn potentiometer. Write for AccuData II Bulletin to Minneapolis-Honeywell, Dept. 34, Boston Division, 40 Life Street, Boston 35, Mass.

Honeywell

First in Control

CIRCLE NO. 159 READER SERVICE CARD



ARE HEAT AND PRESSURE YOUR PROBLEMS?

In a turbine exhaust test facility, 13-inch and 25-inch Allis-Chalmers Butterfly Valves like the one inset above handle gas at 2,000°F. and 180 psig. Carbon steel valve bodies and vanes are sheathed with Inconel. Each body is water jacketed, and the hollow vane, equipped with baffles, is water cooled through trunnion connections. Electric motor drive through a gear reducer provides rapid operation.

Unusual engineering is often required to relate all the factors involved in designing the best valve to solve fluid and gas control problems. If there is no precedence in your own past experience, Allis-Chalmers offers you a broad background of specialized valve engineering and manufacturing skills.

Perhaps a butterfly valve is the answer. It can be made of a number of materials to meet extreme working conditions, will give you uniform flow control through all positions in the normal regulating range. Simplified design and streamlined vanes reduce turbulence and pressure drop, help you save on power.

If you wish to find out more about how we can assist you in solving a fluid or gas control problem, contact your nearest A-C valve representative, or write Allis-Chalmers, Hydraulic Division, York, Penna.

Hydraulic Division — RESEARCH · DESIGN · HYDRODYNAMICS · ENGINEERING · FABRICATION

Rotovalves • Ball Valves • Butterfly Valves • Free-Discharge Valves
Hydraulic Turbines & Accessories • Pumps • Liquid Heaters

AC ALLIS-CHALMERS

1102

CIRCLE 160 ON READER-SERVICE CARD

outer tube by one of several eutectic salt mixtures. When the temperature at any point along the cable reaches a predetermined value, the salt mixture becomes conductive. The short circuit produced may then be used to actuate an alarm or control circuit. Standard elements may be series connected to form lengths of several hundred feet, and elements with different temperature ratings may be used in the same system.—Fenwal, Inc., Ashland, Mass.

Circle No. 300 on reply card

AC ACCELEROMETER

Designed to operate with ac excitation and to provide an ac output voltage, this new linear accelerometer features low output impedance, high output power, and low distortion. Gas damping produces an essentially constant damping ratio over a wide temperature range.

Characteristics:

Range: plus or minus 0.5 to 50g
Total error: within 2 percent
Damping ratio: 0.1 to 2.0, fixed
Output impedance: under 500 ohms
Temperature: minus 60 to plus 160 deg F
—Genisco, Inc., Los Angeles, Calif.

Circle No. 301 on reply card

FOR DC OPERATION

A brand new line of linear displacement transducers combines the inherent advantages of differential transformer construction with built-in solid state converter/demodulator circuits. This design permits dc excitation and also provides a dc signal output. A wide range of excitations, strokes, and scale factors may be specified. Char-

acteristics listed below pertain to the Model LMT-05102.

Characteristics:

Stroke: plus or minus 1 in.
Linearity: within 0.5 percent
Excitation: 6 vdc
Output: plus or minus 2.6 vdc
Dimensions: 6.5 in. long by ¾ in. diam
–G. L. Collins Corp., Long Beach, Calif.

Circle No. 298 on reply card

ANGLE TRANSMITTER

The vane on top of this Model 2562A-3 Angle of Attack Transmitter drives two synchros through a gear train to provide a 26-volt, 400-cycle output signal proportional to angle-of-attack or sideslip. Weighing less than 2 lb, it is said to have a functional accuracy of within 0.2 deg throughout the speed range from 120 knots to Mach 3.0 at sea level. Resistance wire imbedded in the vane serves to prevent ice formation.–Giannini Controls Corp., Pasadena, Calif.

Circle No. 299 on reply card

MAGNETIC ENCODER

Miniature ferrite toroids mounted above a code track of magnetized spots on a barium ferrite disc serve as read-

Even the free flow of CO_2 from a cake of dry ice is difficult to control.

HOW TO RELATE FLOW, VOLUME AND PRESSURE

Shown above is a 24-inch, high-speed Rotovalve installed as a pressure control valve between the blowdown vessels and settling chamber of a Mach 5 wind tunnel operated by the Convair Division of General Dynamics Corporation at San Diego. The valve operates at 600 psig, 400° F., on a one-second, open-to-close cycle. Its rangeability is 150 to 1.

Perhaps you have a similar problem, involving flow, volume, pressure and time. Every special valve application requires the consideration of many questions, in order to relate all the factors that can influence a fluid control problem. This demands specialized engineering . . . the kind you get from Allis-Chalmers.

A-C Rotovalves may be your answer. Their full-line opening offers no obstruction to flow. They may be designed to give you extremely close control of closing time. Positive closure gives completely tight shutoff against either pressure or vacuum.

If you have a fluid control problem, A-C offers you a broad background of specialized valve engineering and application skills. To find out more about how we might assist you, contact your nearest A-C valve representative, or write Allis-Chalmers, Hydraulic Division, York, Pa.

Hydraulic Division RESEARCH DESIGN HYDRODYNAMICS ENGINEERING FABRICATION

Rotovalves • Ball Valves • Butterfly Valves • Free-Discharge Valves
Hydraulic Turbines & Accessories • Pumps • Liquid Heaters

AC ALLIS-CHALMERS

CIRCLE 161 ON READER-SERVICE CARD

New UNION readout instruments withstand shock, vibration and extreme temperature changes

Union Switch & Signal's new READALL* readout instrument replaces complicated systems of lights and relays for reading, storing or transferring all types of information for industrial and military applications. It is not to be confused with conventional indicating devices.

Designed to meet requirements of MIL-E-5422D. The new READALL readout instrument is precision-built and provides instantaneous and continuous operation under conditions of shock, vibration and extreme ranges in temperature. The digital display includes characters in numerical sequence from 0 to 9 plus two blank spaces. 7/32-inch characters can be illuminated red or white as desired; when not illuminated, they appear white against a black background.

Reliability. Performance through one million random operations is an inherent feature of the new READALL instrument. Each module is gasket-sealed in its case to exclude moisture and seal out foreign particles. An especially thin enclosed DC motor, containing ball bearings, permits more efficient operation.

Modular Construction. A unique feature of the readout instrument is its modular construction. It can be used individually or in groups to display multiple characters in a single case.

Direct Code Translation. The operation of the READALL readout instrument is based on a positioning system using a four-bit code. The visual display is the result of a direct electro-mechanical conversion of a binary signal to a decimal read-out. There is no need for additional conversion equipment. Separate code and motor circuits permit the use of the readout instrument in low-level circuitry.

Electrical and Visual Data Storage. Once positioned, the information is displayed until a new code is transmitted to the instrument. No power is consumed while the information is retained. This data may be stored or read-out electrically for further transmission or recording.

Operate Time. The operate time varies from 0.1 second to 1.0 second depending on character position.

Weight and Size. Maximum weight including case is seven ounces; without case, four and one-half ounces. Size encased is 5 13/64 inches long, 1 47/64 inches high and 39/64 inch wide. The new READALL instrument is designed for operation over a temperature range of −54°C to +71°C in humidities up to 100% and altitudes up to 70,000 feet. For more information, write for Bulletin 1019.

*Trademark

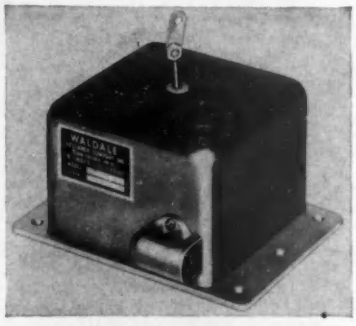
"Pioneers in Push-Button Science"

UNION SWITCH & SIGNAL
DIVISION OF WESTINGHOUSE AIR BRAKE COMPANY
PITTSBURGH 18, PENNSYLVANIA

CIRCLE 162 ON READER-SERVICE CARD

out heads on this new incremental shaft encoder. These heads are phased to provide information on both shaft angle and direction of rotation. Magnetic readout principle makes the encoder immune to the effects of contact wear, dirt and dust, humidity, temperature, pressure, vibration, and acceleration.—Applied Science Corp of Princeton, Princeton, N. J.

Circle No. 302 on reply card



FOR LARGE DISPLACEMENTS

A line of cable-operated position transducers provides accurate measurement of linear displacements from a fraction of an inch to over 180 in. Each contains a precision cable drum mounted on the shaft of a 10-turn potentiometer. A constant-torque spring motor maintains an even tension on the cable. Values given below are for the Model LTD-106-50.

Characteristics:

Lincar travel: 50 in.
Sensitivity: 0.15 mv output per volt excitation per in. travel
Overall linearity: within 1 percent
Dynamic response: to 4g.
Excitation: 6 volts dc nominal; 15 volts max
Cable tension: 1.5 lb
—Waldale Research Co., Inc., Pasadena, Calif.

Circle No. 303 on reply card

DISPLACEMENT-SENSITIVE

Complete units, ready for direct connection between input source and required preamplifier, the Models 580 and 581 linear displacement transducers include differential transformers, stainless steel shields, carbide-tipped spring-return contact rods, and 10-ft integral cables with suitable connectors. Only difference between the models is the mounting means; the

billions

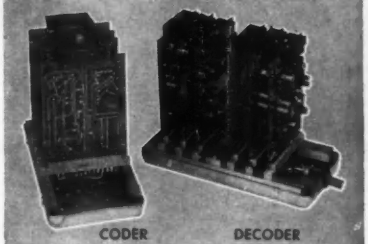
of trouble-free operations with

MONITRON

all-solid-state

SEQUENTIAL SCANNERS

MONITRON is an electronic scanner which monitors from 8 to 256 on-off or go-no-go input signals. Scanning rates range from 15 cps to 1 kc, meeting the bandwidth requirements of almost any application.



CODER DECODER

- **All solid-state components** for years of reliable, maintenance-free service
- **Modular, plug-in design** for instant replacement and future system expansion
- **Fully compatible** with existing telephone, telegraph and microwave practice
- **Available either in integrated systems or component modules**

Anywhere you have need for alarm monitoring, centralized control, or an automatic alarm-and-control closed loop, you'll find that Monitron offers performance advantages over any other system.

Monitron is widely used for supervisory control in pipeline and railroad applications, for microwave alarm systems in unattended stations, and for PDM multiplexing systems. Other uses include telemetering digital information, converting parallel data to serial data, and time multiplexing of slowly changing or quasi-static signals. Cost is comparable with older-style systems; reliability and ease of operation are way ahead.

For more information:

RESEARCH & DEVELOPMENT • PRODUCTION

MOORE ASSOCIATES, INC.

2600 SPRING ST. REDWOOD CITY, CALIFORNIA

CIRCLE 163 ON READER-SERVICE CARD

RAMBLINGS ON INSTRUMENTATION

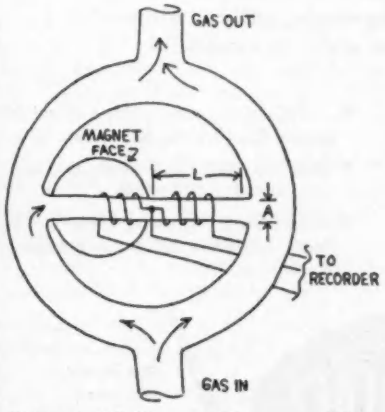
Confessions of an R&D Spy

While waiting nervously for one of the rare audiences granted by our Chief Engineer, our eyes lit on a memo stamped "TOP SECRET" lying on his desk. Feeling somewhat guilty, we scanned it. It began: "Chief, don't blab this to Sprague but . . ."

Feverishly, we read on. The gist of it was that good old R&D had succeeded in developing a new low range oxygen analyzer that meets some rather stringent specs we handed them a short while ago. Not only, we read, does the product meet the specs but it *is already in production!* (Our R&D Department takes a motherly attitude toward new products. When somebody buys one it's almost like having a son leave home. Hence the secrecy.)

Using private-eye methods, we succeeded in ferreting out further information of possible interest to customers. The specs of our new model 632 Analyzer, for instance:

Ranges: 0 to 1%, 0 to 2%, 0 to 3% O_2
Accuracy: ± 2% of Range
Zero Stability: ± 1% of Scale
Time Constant: 5 to 7 seconds
Hydrogen Insensitivity: To 50%



"Magnetic Wind" generated by presence of O_2 in sample produces flow of gas from left to right, cooling left hand and warming right hand windings.

The analyzer works on a new concept of a principle we've proved out for over a decade in our Standard Magno-therm O_2 Analyzer. That is, that oxygen—almost alone among common gases—is paramagnetic. By somehow measuring variations in the paramagnetic properties of a given volume of gas, our analyzer develops a highly accurate reading of its oxygen content. It measures like crazy even when changes are as miniscule as .01% O_2. And there are no moving parts to be oiled, greased, sharpened, ground, re-wound or degaussed.

The important characteristic of Hydrogen insensitivity can be easily explained, according to our Engineer, by this sketch of the analyzing cell coupled with the impressive formula:

$$Q = k \triangle T A \frac{1}{L}$$

where Q is the amount of heat transferred due to the thermal conductivity of the gas. Since A, area of the cell cross member, is small with respect to its half length, L, the value of Q is negligible.

Suppressed Ranges

If your problem is getting an accurate measurement of king-sized quantities of oxygen, we can supply this analyzer calibrated for Suppressed Range O_2, operation, e.g. 98 to 100% or 18 to 21% O_2.

From the foregoing, any man with an oxygen measurement problem can easily deduce that the Hays Low Range and Suppressed Range O_2 Analyzers have features that beggar description. Our Chief Engineer has tentatively agreed to release the complete details to those prospective customers with proper credentials.

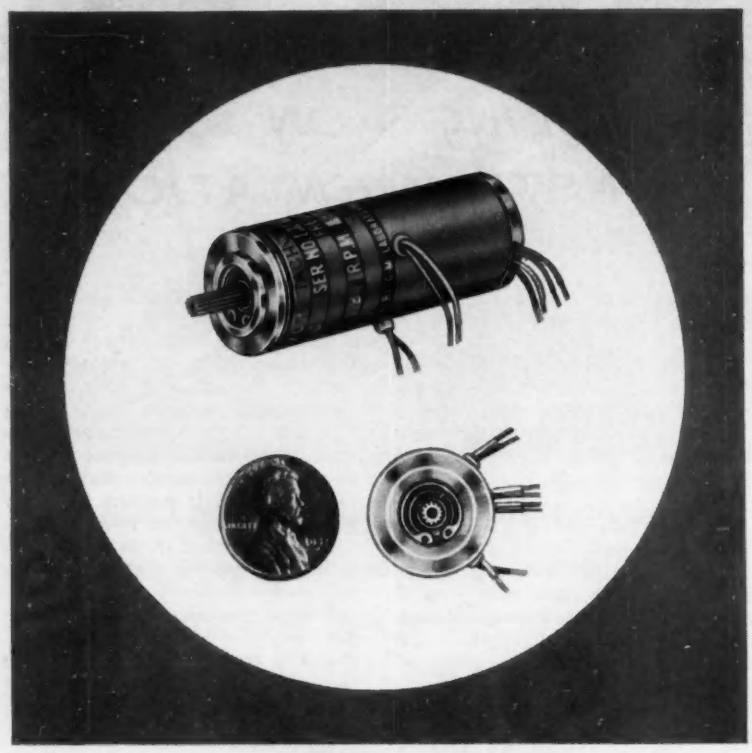
However, I suggest you write directly to me, with or without credentials. Having an intense fiscal involvement in the matter, I personally guarantee to send you either the information or the Chief Engineer himself, whichever appears more lucid.

Phil Sprague Jr.
President

THE HAYS CORPORATION • MICHIGAN CITY 37, INDIANA

CIRCLE 164 ON READER-SERVICE CARD

Spotlight on Space!



NEW GM SIZE 8 MOTOR GENERATOR

for transistor operation

Tested to conform to all applicable Government Specifications for humidity, salt-spray, temperature, altitude, vibration! Promptly available in prototype and sample quantities.

- Outside Diameter: 0.750 inches.
- Weight: 2.9 ounces maximum.
- Tachometer-generator operates on 18 volts, 400 cycles.
- Gradient: 0.23 volts per 1000 RPM.
- Maximum null voltage: 0.015 RMS.
- Both fixed and control phase of motor wound for 18 volts, 400 cycles.
- Stall Torque: 0.3 ounce-inch, with no-load speed of 5400 RPM.
- Pinion Data: Precision Class 2, 13 tooth, 120 pitch, 20° pressure angle.

GM

G-M Servo Motors

manufactured by the Components Division of

G-M LABORATORIES INC.

4340 N. Knox Avenue • Chicago 41

Write for full information, G-M Recommended Procurement Specification No. 665 and Catalog.

CIRCLE 165 ON READER-SERVICE CARD

NEW PRODUCTS

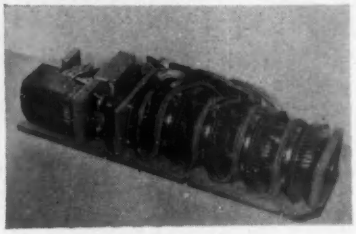
580 is designed for flange mounting, and the 581 threaded for mounting in a tapped hole.

Characteristics:

Max stroke: plus or minus 0.050 in.
Linearity: within 0.5 percent
Excitation: 5 volts at 2400 cps
Contact pressure: 100, 25, or 10 grams
–Sanborn Co., Waltham, Mass.

Circle No. 304 on reply card

CONTROLLERS, SWITCHES & RELAYS



SCANS 160 PRESSURES

Designed originally for wind tunnel studies, but suitable for any multiple-pressure system, this Model SP-105 scanner consists of four rotors, four stators, a motor, switching mechanisms, and electrical and pressure connections. Each rotor-stator assembly accommodates 40 pressure inputs, sequentially coupling each of these to one of four flush-diaphragm transducers. Thus, 16 transducers are time shared by 160 individual pressures. Rotors are driven on a common shaft by a 115-volt, 400-cycle, $\frac{1}{10}$-hp motor. Unit handles measured and reference pressures up to 100 psia. Overall dimensions are 20 by 6 by 4 in.–Datex Corp., Monrovia, Calif.

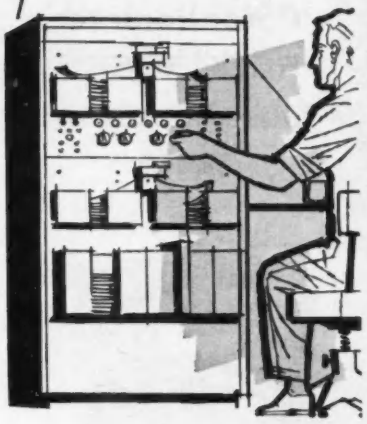
Circle No. 305 on reply card

SELF-CONTAINED

A new photoelectric relay for indoor limit switch applications uses a cadmium sulfide power cell to eliminate the need for tubes and separate control boxes. It will perform 200 operations per min with an illumination level as low as 25 ft-candles. Expected life of the output relay, with a 1-amp, 115-volt ac resistive load, is conservatively rated at 1 million operations; mechanical life exceeds 100 million operations. Designed to mount in any position,

This is the New

TALLY



Tape Preparation & Editing Console

It makes error-free paper tape

By automatically verifying and/or duplicating paper tapes. The console consists of a numerical keyboard, two punch tape readers and one tape perforator. The buffer storage system uses unique Tally Logic Switches.

It features...

Tape to tape duplication and verification at 60 characters per second

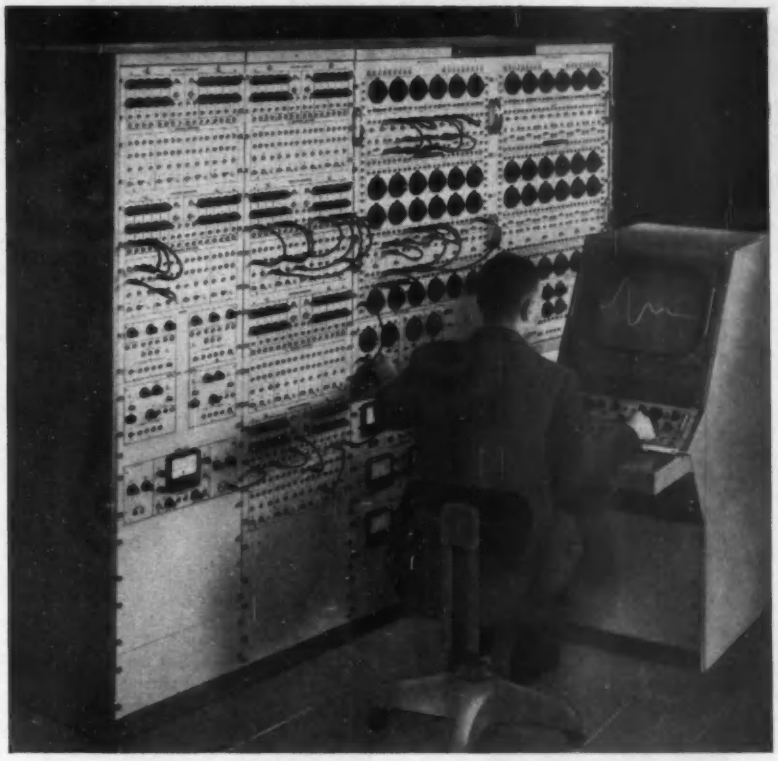
- Keyboard visual display and shift register to eliminate copying errors and operator fatigue in both punching and verifying modes
- Tape corrections without over punching or splicing.

It's ready for delivery now

For complete technical information, prices, delivery, and the name of your nearest Tally engineering representative who will be happy to arrange for a demonstration, please address Dept. 089.

TALLY REGISTER CORPORATION
5300 14th Avenue N.W., Seattle 7, Wash.

CIRCLE 166 ON READER-SERVICE CARD



THE ONLY AVAILABLE
STATISTICAL-ANALOG COMPUTER

The GPS Statistical-Analog Computer is without a doubt the most advanced in the state of the art, and is in every sense of the meaning . . .

- **A TRULY HIGH-SPEED, HIGH CONFIDENCE-LEVEL COMPUTER**
- **A TREMENDOUS TIME AND MANPOWER SAVER***
- **UNRIVALLED OR UNEQUALLED IN PERFORMANCE**
- **VERSATILE IN APPLICATION**

The basic GPS computer is a compressed time-scale analog computer which operates 3000 times faster than real time. A solution is generated and repeated automatically at rates up to 50 times/sec. As many as 3000 independent runs or solutions can be statistically evaluated in a minute of time.

With the GPS computer you eliminate the drudgery of routine analyses, the endless footage of data recording, and the subsequent tedious data reduction.

Because of the new design principle and inherent versatility, the GPS computer provides immediate computation of the statistical and dynamic characteristics of:

- *Missile guidance and control systems*
- *Radar systems in general*
- *Process and quality control*
- *Flight control*

*An analysis of a missile miss-distance was conducted at the GPS COMPUTER CENTER by the research laboratory of a large aircraft firm. Their report stated that, "25 times as much data (with higher confidence-level) was collected in one week on the GPS computer as was collected and analyzed in 4 months time on a slow-speed computer"

Our engineers are ready to assist you.
For further details please write or call Dept 21

GPS INSTRUMENT CO., Inc.

180 NEEDHAM STREET • NEWTON 64, MASS.

VARIAN
Potentiometer
RECORDERS
Used by the thousands
because . . .

1. THEY ARE TRULY
PORTABLE

The Varian G-11A weighs only 15 pounds and can be carried anywhere in the laboratory, plant or field. And because it is a potentiometer recorder, it is highly sensitive and can be adapted to extremely varied recording requirements.

Varian recorder prices from $365; full-scale balancing time 1 or 2½ seconds; ranges from 0-9 millivolts to 0-100 volts, wide choice of speeds, accessories and charts. Full specifications and description available by writing the Instrument Division.

VARIAN
associates
PALO ALTO 40, CALIFORNIA

CIRCLE 167 ON READER-SERVICE CARD

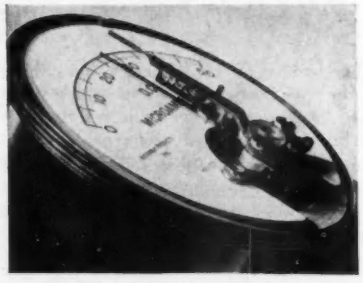
the unit is supplied with a 9-ft length of cable.–General Electric Co., Schenectady, N. Y.

Circle No. 306 on reply card

MOTOR-DRIVEN

A line of high-speed, motor-driven sampling switches has recently been developed for such diverse applications as dc signal chopping, waveform generation, amplifier stabilization, strain gage and thermocouple sampling, etc. Composite unit shown above consists of three 24-way, low-speed switches driven through a precision gearhead, and three 24-way, high-speed switches driven directly at motor speed. Other units are available with as many as twelve switches at each end and gear ratios up to 600:1. Vactric Ltd., London, England.

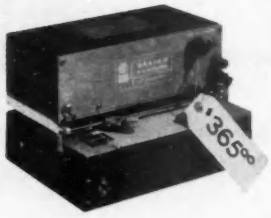
Circle No. 307 on reply card



CONTINUOUS READING

Complete redesign of the adjustable set-point arm on this new meter-relay permits continuous indication of the true signal strength, even after the load relay has been energized. Control action begins when a round vertical contact on the indicating pointer meets a flat contact on a spring-loaded toggle mounted beneath the set-point arm. The moving pointer, with its torque increased by a booster coil, passes by the toggle and continues to

VARIAN
Potentiometer
RECORDERS
Used by the thousands
because . . .



2. PERFORMANCE AT
LOW COST

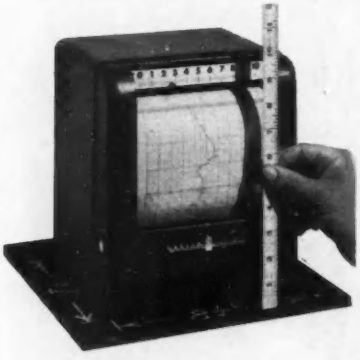
As little as $365 for a sensitive, rugged potentiometer recorder. Varian Recorders are accurate to 1% and rugged enough to do round-the-clock production-line checkout or round-the-calendar monitoring of long-term laboratory experiments.

Full-scale balancing time 1 or 2½ seconds; weight 15 pounds; ranges from 0-9 millivolts to 0-100 volts; wide choice of speeds, accessories and charts. Full specifications and description of models available by writing the Instrument Division.

VARIAN
associates
PALO ALTO 40, CALIFORNIA

CIRCLE 168 ON READER-SERVICE CARD

VARIAN
Potentiometer
RECORDERS
Used by the thousands
because . . .



3. ANYWHERE USED, THEY

SAVE SPACE

Equipment manufacturers praise the Varian G-11A because it fits neatly into instrument panels, occupying ¼th the space of a conventional-sized recorder. Lab men appreciate Varian's portable versions because they add so little clutter to bench or table.

1% limit of error; 1 or 2½ second full-scale balancing time; ranges from 0-9 millivolts to 0-100 volts; wide choice of speeds, accessories and charts; prices from $365. For all the facts, write the Instrument Division.

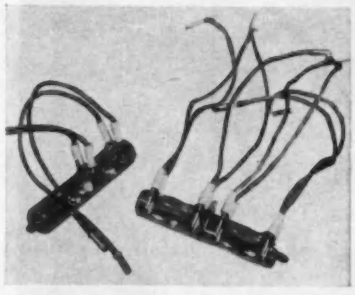
VARIAN associates
PALO ALTO 40, CALIFORNIA

CIRCLE 169 ON READER-SERVICE CARD

NEW PRODUCTS

show actual signal strength. When the signal returns to set point, the pointer contact snaps the toggle the other way and reverses the control action. Meter-relays with this new design will handle virtually any application requiring a single set point.—Assembly Products, Inc., Cleveland, Ohio.

Circle No. 308 on reply card



"ONE-WAY" DESIGN

A new line of mercury switches, two models of which are shown here, features a unique one-way operation. Within each switch, mercury flow is controlled in such a way that a momentary wipe contact is produced when the switch is tilted 10 deg or more in one direction, and no contact is made as the switch returns to its original position. A standard-size switch, measuring 2¾ in. long by ½ in. in diam, will carry 5 amp at 115 volts with inrush overloads to 10 amp.—American Designed Components, Inc., Jericho, L. I., N. Y.

Circle No. 309 on reply card

SWITCHING COMMUTATOR

A new lightweight, miniature switching commutator, available either motor driven or hand detented, features low noise, low torque, long life, and an angular accuracy within 10 min of arc. —Airflyte Electronics Co., Bayonne, N. J.

Circle No. 310 on reply card

PLUS. . . .

(311) **Kurman Electric Co.**, Brooklyn, N. Y., has introduced the Series 51C Midget Relay, said to be the smallest, lightest **plate circuit relay** with self-wiping contacts. . . . (312) A heavy-duty, oil-tight **limit switch** that can be replaced without disturbing wiring is now offered by the **Square D Co.**,

VARIAN
Potentiometer
RECORDERS
Used by the thousands
because . . .

4. ACCESSIBILITY IS

NOTE-ABLE

The Varian G-10's open, horizontal chart is the delight of any man who writes notes. And this recorder is so compact that it can be moved right in close to the work, letting you keep your eyes on the experiment and your pencil on the chart.

Prices from $365; 1% accuracy; 1 or 2½ second full scale balancing time; adjustable or fixed spans 10 to 100 millivolts; wide choice of speeds and accessories. Full specifications and description in Varian literature. Write the Instrument Division.

VARIAN associates
PALO ALTO 40, CALIFORNIA

CIRCLE 170 ON READER-SERVICE CARD

C & S Force Calibrators

With guaranteed direct reading accuracies of 1/20 of 1%, these Cox and Stevens kits set new standards of precision and portability in force and weight measurement. They combine the high accuracy of laboratory equipment with the ruggedness required for field service.

C & S Force Calibrators are designed for on-the-spot, field calibration of testing machines, thrust stands, electronic, hydraulic or lever weighing systems, and can also be used for general purpose, single-point weighing operations. Containing a single load cell, the kits are light, compact and easy to use; available in capacities of 5,000 to 100,000 pounds.

Here are some of the features:

1. High guaranteed accuracy: 0.05% of applied load
2. Fast, direct reading: no conversions or corrections needed
3. 115 V AC operation (24 V DC optional)
4. Compact: All instrumentation, adapters, etc. in one carrying case
5. Portable: Watertight case weighs approximately 50 pounds
6. Easy to use: 50 foot cable plugs into cell
7. Rugged: Multi-column cell has an overload capacity of 225% of rated load

REVERE CORPORATION OF AMERICA

Wallingford, Connecticut

Send for Bulletin 3006 now!

94

A SUBSIDIARY OF NEPTUNE METER COMPANY

neptune

CIRCLE 171 ON READER-SERVICE CARD

NEW PRODUCTS

Milwaukee, Wis. . . . (313) The Model 55-A-1 **Perma Brush Commutator,** just announced by **General Devices, Inc.,** Princeton, N. J., provides 30 shorting channels and operates at 5 rps. . . . (314) **Electrosnap Corp.,** Chicago, Ill., recently released specifications on a new solenoid-held pushbutton **panel switch** in which the pushbutton is of colored plastic and illuminated from behind.

Circle No. 311, 312 or 313, 314 on reply card

POWER SUPPLIES

COMPLETELY ISOLATED

Use of a specially shielded transformer and unique feedback circuits completely isolates the output of this transistorized dc power supply from both line voltage and line ground. The unit provides 0 to 20 volts at 1 amp and is well suited for use with equipment such as single-ended strain gage amplifiers and differential amplifiers. A special output receptacle permits remote shielding of the power cables.—Moeller Instrument Co., Inc., Richmond Hill, N. Y.

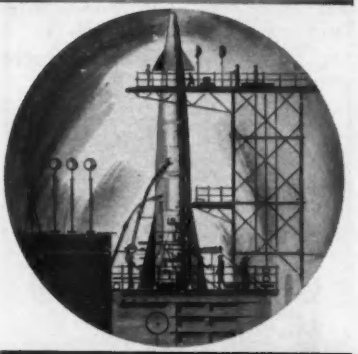
Circle No. 315 on reply card

DIRECT CONVERSION

Still undergoing tests, a new "fuel-cell" for producing electricity directly from gaseous fuels may prove to be the answer to power supply problems in military and space vehicle applications. Current model is disc-shaped with a 3-in. diam and 1½ in. thick. It features a plastic ion exchange membrane between its electrodes. Hydrogen and oxygen are fed to opposite sides of this membrane. On one side,

Atchley SERVOVALVES

FIRST IN RELIABILITY



MODEL 415

The Model 415 flow rate is 10 GPM for 1000 psi drop across the valve. Because of unique jet construction, particles as large as 200 microns can be passed through both the first and second stages without malfunctioning.

Other features include:

Single source of oil in first stage eliminates possibility of unbalance or "hardover" signals due to oil contamination.

Second stage precisely controlled by a push-pull, frictionless, force feedback servo.

Other models available in four sizes with flows from ½ to 50 GPM.

For more information, write for Data File CE-644-3.

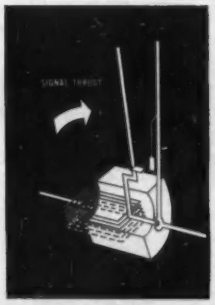
Raymond Atchley, Inc.
2340 SAWTELLE BOULEVARD
LOS ANGELES 64, CALIFORNIA
TELEPHONE • GRANITE 9 8626

CIRCLE 172 ON READER-SERVICE CARD

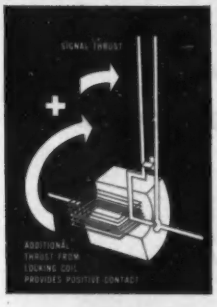
10,000,000 PERFECT OPERATIONS: reliability . . . achieved by the remarkable A.P.I. meter-relay

Suitable for any electrically-measurable variable, the A.P.I. meter-relay gives you sensitive monitoring, reliable control, combined in a single compact unit. It is an essentially simple instrument, yet a highly accurate and dependable one.

HERE'S HOW IT WORKS



1. Basically, the A.P.I. meter-relay is an indicating meter with built-in contacts. One contact is on the moving (signal-indicating) pointer; the other, on the adjustable (set-point) pointer. The indicating pointer is a free-moving element. The meter-relay has the high sensitivity inherent in a well-designed D'Arsonval movement.



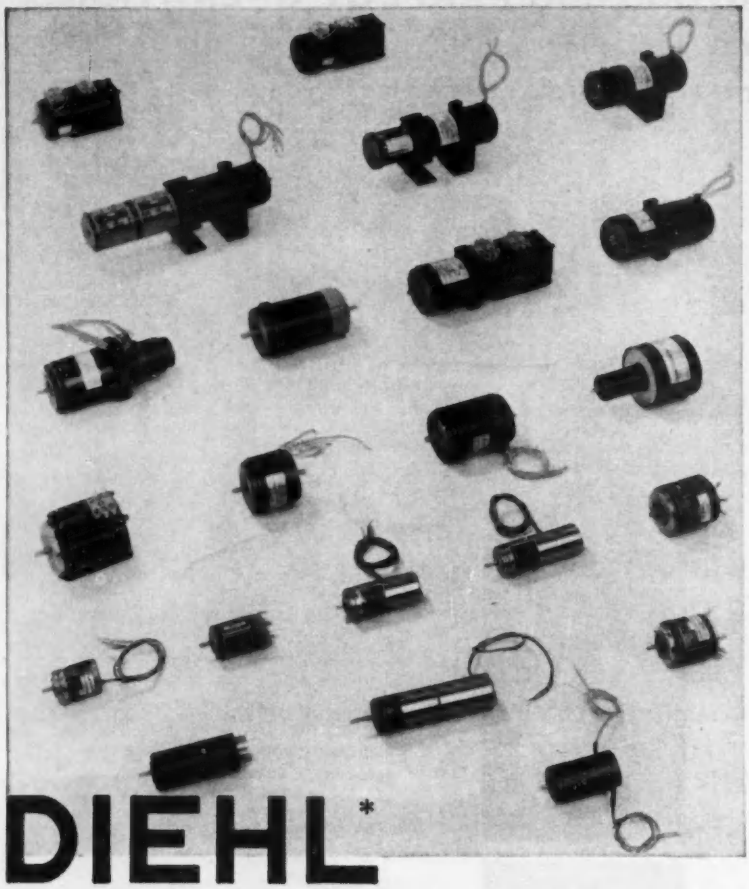
2. At the instant of contact, a locking coil, wound integrally with the armature coil, supplements the torque developed in the meter movement. It is this locking coil — exclusively featured by A.P.I. — that assures positive contact every time. It holds the contacts together, maintains firm pressure to provide a good control circuit.

3. "Making" of the contacts loads the flexure spring on the set-point contact arm. When the contacts are released, they are immediately pushed apart by the force of the spring-loaded arm. There is no teasing or sticking; the break is decisive. Wiping action keeps contacting surfaces clean.

If you need fully-reliable, stable control at a practical cost, you ought to have a look at our Catalog 4E. A copy is yours on request.

api **ASSEMBLY PRODUCTS, INC.**
Chesterland 77, Ohio

CIRCLE 173 ON READER-SERVICE CARD



DIEHL*

The growing family of instrument servo components

60 cycle Servomotors (1, 3, 5 and 10 watts)
400 cycle Servomotors (3 and 15 watts)
60 cycle A.C. Tachometers
400 cycle A.C. Tachometers
D.C. Tachometers
Gear Reducers
Vacuum Tube Servo Amplifiers
SERVOPOT (Combination of: Servomotor, gear train, slip clutch and potentiometer)
Available separately or in any combination

I.S.A. Conference and Exhibit Booth 673 International Amphitheater Chicago, Ill. Sept. 21-25, 1959

DIEHL Instrument Servo Components have been developed to offer maximum performance, flexibility and reliability at minimum cost. These are the basic servo system building blocks which enable our military and industrial customers to satisfy the demands placed on them for higher over-all response, accuracy and economy. *Write for full details concerning any of these components.*

Diehl

DIEHL MANUFACTURING COMPANY
A SUBSIDIARY OF THE SINGER MANUFACTURING COMPANY
Somerville, New Jersey

SINGER

• AC SERVOMOTORS • AC SERVOMOTORS WITH AC TACHOMETERS • DC SERVO SETS
• AC SERVOMOTORS WITH DC TACHOMETERS • AC AND DC TACHOMETERS • RESOLVERS

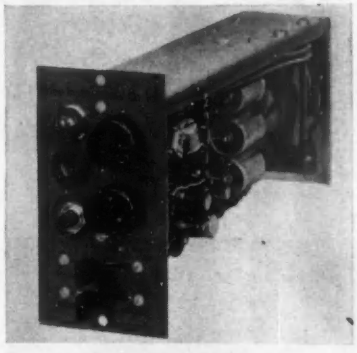
*A Trademark of DIEHL MANUFACTURING COMPANY

CIRCLE 174 ON READER-SERVICE CARD

NEW PRODUCTS

the hydrogen molecules break up into electrons and positively charged hydrogen ions; the electrons flow through the external circuit, and the hydrogen ions through the membrane. On the other side, oxygen combines with the hydrogen ions and electrons from the external circuit to form water. Current densities as high as 30 ma/cm² and thermal efficiencies over 60 percent have been obtained.—General Electric Co., Schenectady, N. Y.

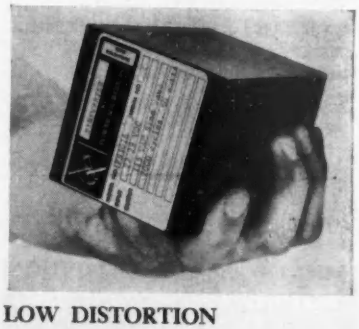
Circle No. 316 on reply card



STRAIN GAGE CONTROL

Designated Model SRB-200, this compact module combines a strain gage power supply with the strain gage balance and calibration circuitry. An internal switch permits selection of either constant-current or constant-voltage operation. Line and load regulation is within 0.1 percent. Maximum noise to ground is only 10μv peak-to-peak when measured with a strain gage of 350-ohms impedance.—Video Instruments Co., Inc., Santa Monica, Calif.

Circle No. 317 on reply card



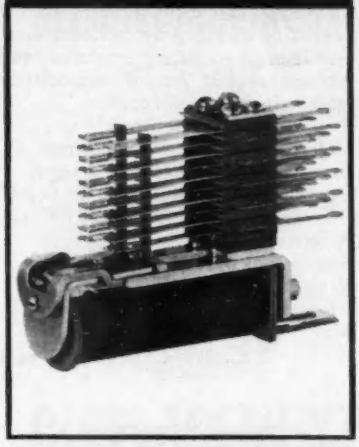
LOW DISTORTION

Shown is the Model SV2C1200 Sineverter, a general-purpose inverter for use in missiles, aircraft, and other

Stromberg-Carlson

"TELEPHONE QUALITY"

Relays



. . . featuring new high-voltage types for test equipment or other high-voltage applications.

THE insulation in the new relays carries 1500 volts A.C.—three times normal. These high-voltage models are available in Types A, B and E. They are the latest additions to the Stromberg-Carlson line of twin contact relays—all available for immediate delivery.

The following regular types are representative of our complete line:

Type A: *general-purpose relay with up to 20 Form "A" spring combinations. This relay is excellent for switching operations.*

Type B: *a gang-type relay with up to 60 Form "A" spring combinations.*

Type BB: *relay accommodates up to 100 Form "A" springs.*

Type C: *two relays on the same frame. A "must" where space is at a premium.*

Type E: *has the same characteristics as the Type A relay, plus universal mounting arrangement. Interchangeable with many other makes.*

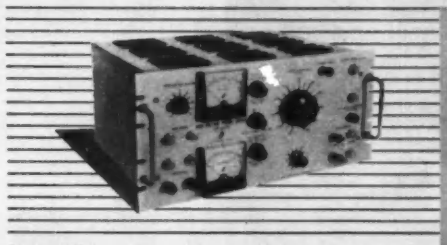
Complete details and specifications are contained in our new relay catalog, available on request. Write Stromberg-Carlson Telecommunication Industrial Sales.

STROMBERG-CARLSON
A DIVISION OF **GENERAL DYNAMICS**
112 CARLSON RD. • ROCHESTER 3, N.Y.

CIRCLE 175 ON READER-SERVICE CARD

NEW IDEAS IN PACKAGED POWER

for lab, production test, test maintenance, or as a component or subsystem in your own products



Series 1000.

Easy-to-use compact Beta Series 1000 high voltage supplies come in 13 different models, providing voltages up to 60kv dc and currents as high as 500 ma. Adjustable output voltage (0 to max. rating with coarse and fine controls); extremely low ripple; easy, rapid polarity reversal and full metering are a few outstanding features.

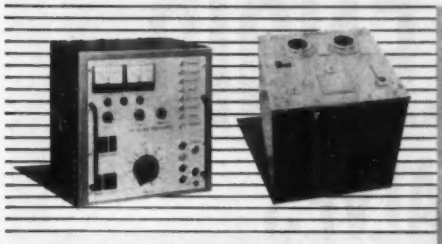
Single-unit, rack-mounting supplies to 60 KV

Available ranges and current capacities:

Output (DC KV)	Current (Max. MA)
0-1	500
0-3	200
0-5	10 or 100
0-10	2, 10, or 50
0-15	5, or 10
0-30	2, 5, or 10
0-60	5 @ 50 KV 1 @ 60 KV

Inputs: 117 vac, 60 cps, single phase

HV DC TO 250KV WITH MAXIMUM CONVENIENCE, SAFETY



Series 2000 – control section (left).
Series 2000 – high-voltage section (right).

Simple to operate, conservatively rated to insure long, optimum performance with maximum safety, Beta Series 2000 supplies come in thirteen different models, with maximum voltages ranging from 1 to 250kv dc. Output voltage continuously adjustable from 0 to maximum. Two-unit design allows optional remote operation of high voltage circuits. For maximum voltages less than 30 kv, the high-voltage unit is air-insulated; for higher voltages, oil-insulated (shipped dry). Every precaution is taken to insure personnel and equipment safety.

Two section supplies to 250KV

Available ratings:

Output (KV DC)	Current (Max. MA continuous)
0-1	3000
0-3	1000
0-5	500
0-10	200
0-20	150
0-30	30
0-30	100
0-50	10, 50
0-120	5
0-120	25
0-150	5
0-250	10

Inputs: 117 vac, 60 cps, single phase

Sorensen markets the widest line of controlled power equipment available today, including: Regulated a-c and d-c supplies, unregulated power supplies, frequency changers, inverters, and converters, SAMES electrostatic generators for regulated voltages up to 600 kv dc, voltage reference sources, high-voltage d-c overpotential testers and high-potential test equipment.

An exceptionally wide selection of standard models is available and experienced Sorensen engineers are always glad to discuss your special needs. 9.13

Sorensen

SORENSEN & COMPANY, INC.

Richards Avenue, South Norwalk, Connecticut

WIDEST LINE OF CONTROLLED-POWER EQUIPMENT FOR RESEARCH AND INDUSTRY

IN EUROPE, contact Sorensen-Ardag, Zurich, Switzerland. **IN WESTERN CANADA,** ARVA. **IN EASTERN CANADA,** Bayly Engineering, Ltd. **IN MEXICO,** Electro Labs, S. A., Mexico City.

CIRCLE 176 ON READER-SERVICE CARD

MINIATURE SOLENOID VALVES

• Small Size: (1½"x2¾") • Large Capacity
• Packless—only 2 moving parts

Available in 2- and 3-way normally open and closed types, this new line of solenoid valves has a pressure range from 0 to 400 psi. Bodies can be supplied in stainless steel, brass and aluminum.

NEW FEATURES:

- Operating temperature of +110° C to −65° C—higher temperature requirements can be supplied on special order.
- Many modifications are possible including side, bottom and top metering (3-way and 2-way normally open).
- Several models are U. L. Approved.
- New Type "S" valve designed for completely noiseless operation.

FOR MORE INFORMATION WRITE FOR BULLETIN V.

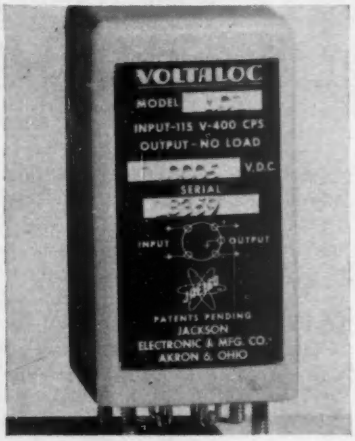
ALLIED CONTROL VALVE DIVISION
ALLIED CONTROL COMPANY, INC.
2 EAST END AVENUE, NEW YORK 21, N. Y. AL-187

CIRCLE 177 ON READER-SERVICE CARD

applications where the primary ac power frequency is 2,000 cps. Unit operates with a 22-29-volt dc input and produces an output of 115 volts, 2,000 cps, single-phase, 0-50 va. It cannot be damaged by overload, short circuit or open circuit operation, and resumes normal output immediately upon removal of the fault.

Characteristics:
Voltage regulation: ±5 percent
Frequency regulation: ±1 percent
Operating temp: −20 to +85 deg C
Vibration: to 10g at 2,000-3,000 cps
Acceleration: 12g
Size: 3 by 3 by 4 in.
Weight: 3 lb
—Power Sources, Inc., Burlington, Mass.

Circle No. 318 on reply card



ULTRA-STABLE

Available for 60- and 400-cycle operation, this new Voltaloc voltage standard features a regulation of one millionth of 1 percent for any change in input voltage from 90 to 150 volts. Designed to operate in any position and withstand extreme environments, it makes an ideal substitute for chemical type cells in many applications. Units with outputs up to 5 vdc are available.—Jackson Electronic & Mfg. Co., Akron, Ohio.

Circle No. 319 on reply card

PLUS. . . .

(320) **A constant current source**, with a range of 0.1 μa to 150 ma at 0 to plus or minus 100 vdc, has been designed for precision gyro measurements by **North Hills Electric Co.**,

TRY THIS FRESH APPROACH

to the measurement of displacement

IRC

DISPLACEMENT TRANSDUCERS

No longer are weak outputs a problem in the application of displacement transducers to the measurement or indication of mechanical movements electrically.

You have a reliable source for displacement transducers—International Resistance Company—offering you a vastly superior precision product *at a lower cost.*

Better Linearity—as low as 0.1%
Better Sensitivity—2.0 MV/Volt Input/Mil at 60 cycles
Linear Range: .005" to 4.0"
Frequency: 50 to 20,000 CPS
Null Voltage: 0.25% of total output, or less
No moving parts to wear
Longer, Infinite Life
Resolution: Infinite
Precision assured by close control at every step in manufacture

Special designs available for:
- **High temperature (1200°F)**
- **Nuclear radiation resistance**
- **120V. inputs; up to 50V. outputs**
- **Zero temperature coefficient**
- **Matched units for complete interchangeability**

For complete information including many more advantages of IRC Displacement Transducers write for Bulletin R-3b.

Compu-tran

International Resistance Company
COMPUTER COMPONENTS DIVISION
Dept. 241, 401 N. Broad St., Philadelphia 8, Pa.
In Canada: International Resistance Co., Ltd. Toronto, Licensee.

CIRCLE 178 ON READER-SERVICE CARD

NEW !

The 603-607 and the 621 series of direct recording oscillographs, the newest in Midwestern's **EXPANDED** line of precision electronic test data instruments, are the results of years of proven leadership in the field of oscillography. Write for complete brochures and performance information.

UNEQUALLED PERFORMANCE!

603 & 607 SERIES D/R OSCILLOGRAPHS — 50 traces — 12" record — 20 record speeds (.071 to 173 ips) — 6,000 cps flat response.

LOWEST COST!

621 SERIES D/R OSCILLOGRAPHS 14 traces — wide range of record speeds — 6,000 cps flat response.

IF YOU NEED . . .
- Oscillographs
- Galvanometers
- Amplifiers
- Bridge Balance Units
- Discriminators
- Voltage Controlled Oscillators
- Magnetic Tape Recorders
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- Current Sources
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- Torque Motors
- Servo Amplifiers
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- Aircraft Data Acquisition Recorders
- Complete FM Ground Station Telemetering Systems

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also manufacturers of Magnecord fine tape recording instruments

CIRCLE 179 ON READER-SERVICE CARD

NEW

HIGH-SPEED RECORDER

ITT Storascope

ITT STORASCOPE, TYPE 8LS-218

...for recording non-recurring events

ADVANTAGES

- Instantaneous recording
- Long storage period
- Short erasing time
- Manual or self-advancing position
- Automatic contrast adjustment
- Low cost CRT

APPLICATIONS

This instantaneous all-electronic recorder is designed for useful application in the investigation of technical problems in such fields as RESEARCH, TESTING, COMPUTING, ACOUSTICS, and MEDICAL ELECTRONICS, where the recording of non-recurring events (periodic or non-periodic) is of particular interest.

FEATURES

The data are recorded on a special dark trace Cathode Ray Tube by purely electronic means and can remain visible for several days or can be erased at any time within a matter of 20 seconds. The viewing area can be used for a single phenomenon, suitably amplified, or can be subdivided through a stepped position control to record up to 10 different waveforms. If so desired, this control may be set to "AUTO" and the trace will be shifted automatically by approximately one centimeter with each new trigger signal. When a special low erasing signal is applied to the screen, the recordings will be continuously erased so that the top line is usable again as soon as the last line is completed.

X-Y PLOTTING

Since the horizontal sweep can be replaced by an external voltage, the Storascope can be employed for x-y plotting.

NO SPECIAL RECORDING CAMERA REQUIRED

The picture contrast is sufficient for making photographic records with simple cameras, since the exposure time can be prolonged as required. Built-in glare-free illumination of the screen enhances the contrast of the dark-blue picture to the bright background and thus makes possible observations in dark rooms.

TYPICAL SPECIFICATIONS

Frequency range: 0 to 10 kc
Y sensitivity: 3 V/cm
X sensitivity: 1 V/cm
Time base: 0.01 to 10 secs.
Storage time: Several days
Erasing time: Approximately 20 secs.
Screen area: 3½" x 5"
Input: 100 kΩ, unbalanced

Write, wire, or phone for complete technical data and price information on the ITT Storascope as well as other products of the Industrial Products Division, including Large Screen Oscilloscopes, Test Instruments, Custom Power Equipment, and Closed-Circuit Television.

ITT Industrial Products Division
INTERNATIONAL TELEPHONE & TELEGRAPH CORPORATION
15191 BLEDSOE STREET • SAN FERNANDO, CALIFORNIA
TELEPHONE EMPIRE 7-6161

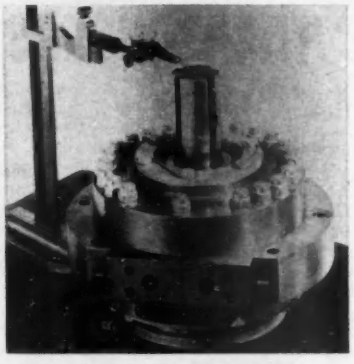
CIRCLE 180 ON READER-SERVICE CARD

NEW PRODUCTS

Inc., Mineola, L. I., N. Y. . . . (321) The Model 738-001 solid-state **laboratory power supply,** offered by the **Western Design Div. of U. S. Industries, Inc.,** Santa Barbara, Calif., provides a 0 to 3 amp, 130 vdc output with less than 1 percent ripple. . . . (322) **Power Supplies, Inc.,** Highland, Ill., recently announced development of a new 100-va static, **constant-frequency converter** for use in computers, autopilots, gyros, and servos.

Circle No. 319, 320, 321, or 322 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS



HIGH TORQUE OUTPUT

Photo shows one of three new rotary power hydraulic actuators designed especially for critical ground applications. These units provide power for rotary vibration testing, angular load testing, high-powered angular positioning in flight simulation tables, etc. Weights range from 36 to 80 lb. and stall torques from 8,700 to 19,000 lb-in. at 3,000 psi. Frequency response of all models is flat from 0 to 200 cps.—Royal Industries, Inc., Pasadena, Calif.

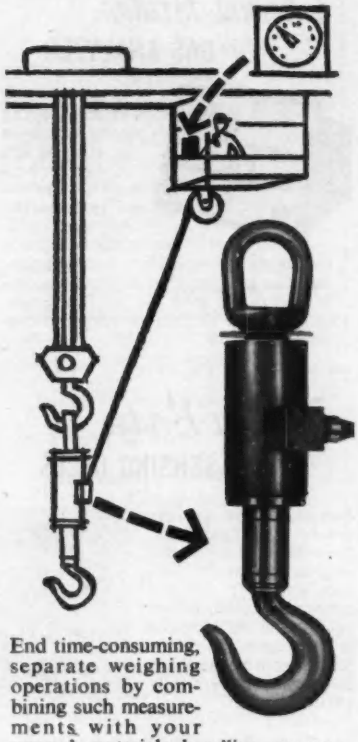
Circle No. 323 on reply card

FOR HOT SERVICE

A brand new high temperature solenoid for aircraft and missile applications operates continuously at ambient temperatures up to 1,000 deg F. The unit is designed for strokes of from 0.010 in. to 0.060 in. Minimum

MEASURING WEIGHT?

Save handling time with easy-to-install, remote-indicating SR-4® Crane Scales



End time-consuming, separate weighing operations by combining such measurements with your normal materials handling program. SR-4® Crane Scales provide you with accurate inventory control information—on remote dial or printer type indicators—while materials are being moved. SR-4® Crane Scale sensing elements contain no moving parts; require no maintenance; and are unaffected by dirt, grease, water or corrosive fumes. Connection to indicator consists of only a light, flexible electrical cable. Accuracies guaranteed to ±0.2% of capacity. Available for immediate delivery in various capacities from ½ through 25 tons.

For 12-page Bulletin No. 4513 write Dept. I-6

FIRST in force measurement

SR-4 BALDWIN BLH LIMA-HAMILTON

BALDWIN·LIMA·HAMILTON

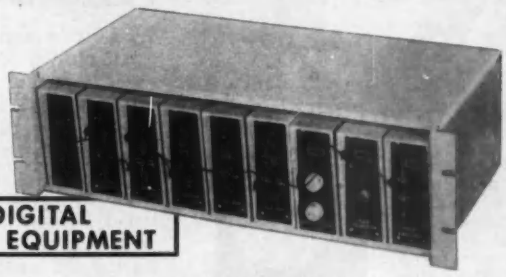
Electronics & Instrumentation Division
Waltham, Mass.

SR-4® Strain Gages • Transducers • Testing Machines

CIRCLE 181 ON READER-SERVICE CARD

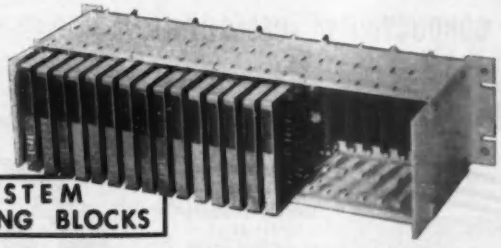
digital offers all the advantages of the BUILDING BLOCK CONCEPT

- Full selection of transistorized logic packages
- Complete freedom and flexibility of application
- Time-saving ease of assembly and reassembly
- Speeds up to 5 megacycles per second
- Economy in slow-speed applications



DIGITAL TEST EQUIPMENT

Packaged in convenient building block form, DEC Test Equipment units can be assembled quickly and easily by means of banana-jack patch cord interconnections to form custom digital test instruments such as signal generators, counters, pattern generators, etc.



SYSTEM BUILDING BLOCKS

Featuring saturated circuits with wide operating margins, DEC System plug-in units provide the designer complete flexibility in formulating the logic for permanent or semi-permanent digital systems.

Write or call for complete technical information.

digital | EQUIPMENT CORPORATION

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CIRCLE 182 ON READER-SERVICE CARD

ELECTROLYTIC CONDUCTIVITY EQUIPMENT

CONDUCTIVITY BRIDGES

Industrial Instruments offers a **complete** line of electrolytic conductivity bridges for the measurement and control of solution concentration. Standard models are available for use in conductive solutions ranging from distilled water to concentrated acids or alkalis, and in all temperature ranges.

CONDUCTIVITY CONTROLLERS

For steam generation, water purification, chemical processing general lab work, and wherever continuous indication and/or control of solution conductivity is required Industrial Instruments has a wide line of practical instruments designed specifically for the job. Also available are conductivity recorders in circular and strip-chart, single and multi-point types as well as battery-operated units.

CONDUCTIVITY CELLS

A single source for all your cell needs. Body materials in the widest range of materials to meet every requirement for temperature, pressure and corrosion resistance. Complete selection of cells designed to meet your application requirements...no universal compromises. Nickel platinum, graphite, gold or tin electrode materials as well as a comprehensive selection of cell constants and ranges for every measurement application.

Write for your personal copy of our new Catalog #23.

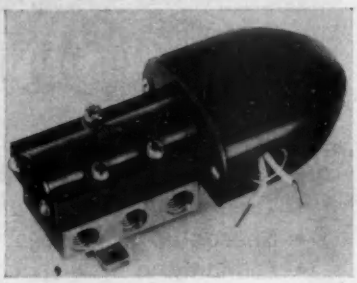
Industrial Instruments Inc.

89 Commerce Road, Cedar Grove, Essex County, N. J.

CIRCLE 183 ON READER-SERVICE CARD

force developed for a 0.010-in. stroke at 1,000 deg F is 15 lb. Coil operates on 18 to 30 vdc.—Rocker Solenoid Co., Wilmington, Calif.

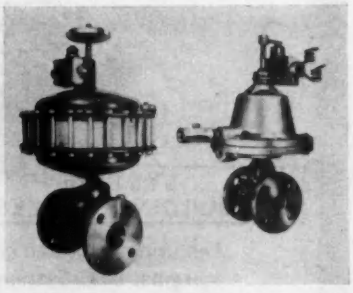
Circle No. 324 on reply card



PACKLESS DESIGN

All working surfaces on the body and spool of this new four-way solenoid valve are honed and lapped to within 50 millionths of an inch and treated to provide a hardness equivalent to that of tungsten carbide. This, the manufacturer maintains, preserves indefinitely the sealing surfaces. Designated Model "A", the valve is designed for 200 psi or vacuum air service and includes a standard subbase mounting with ¼-in. threaded ports. Single units list for $34.50. Actuators, other than solenoids, are optional.—Alkon Products Corp., Hawthorne, N. J.

Circle No. 325 on reply card

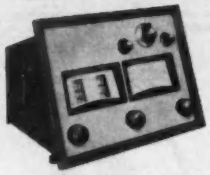


SPRINGLESS OPERATORS

Available with either a pressed steel or cast aluminum housing, a new air-loaded valve operator has been developed for use on miniature valves. The unit features a large air chamber on one side of its diaphragm which is pneumatically loaded to any desired pressure and sealed by a check valve. Signal air pressure on the other side of the diaphragm must exceed this preloading pressure to move the valve

THERMAL CONDUCTIVITY EQUIPMENT

Therma Bridge GAS ANALYZER



For monitoring purity values in gas streams and for wide applications in gas impurity analysis. Completely self-contained unit with sensing cells, precision machined gas trains, newly designed dessicant drier columns, control circuit and power supply. Functionally designed with all controls located in convenient positions.

Therma Bridge SENSING CELLS

Advanced design provides greater output response. Available in two metal mass weights. Heavyweight, open-core, hexagonal cell and light-walled, individual cavity type. All units provide low background noise, super-smooth electrical balance, improved sensitivity and heat transfer.

Therma Bridge POWER SUPPLY

Power supply and control circuit unit readily adaptable as a power source for any thermal conductivity sensing cell or for any other requirement demanding a precisely regulated output voltage and currents between 30 and 500 milliamperes. Unit utilizes selenium rectifier full wave bridge circuit with high efficiency transistorized error amplifiers.

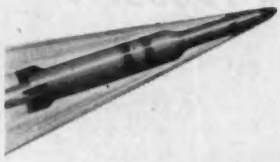
Write for descriptive literature...

Industrial Instruments Engineering Corp.

89 Commerce Road, Cedar Grove, Essex County, N. J.

CIRCLE 184 ON READER-SERVICE CARD

ELECTRONICS: Over, on and under...



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Here's your opportunity to join the team that developed the nation's first transistorized portable digital computer with "Big Computer" capabilities.

Autonetics now offers you advanced opportunities in the design, research, development, test and checkout, manufacture, sales and field service of digital computers. Apply your experience to:

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BSEE or better is preferred, along with several years experience in either systems or components associated with digital computers in circuits, memories, input-output equipment, logic design, analysis, or programming.

Send your resume to:

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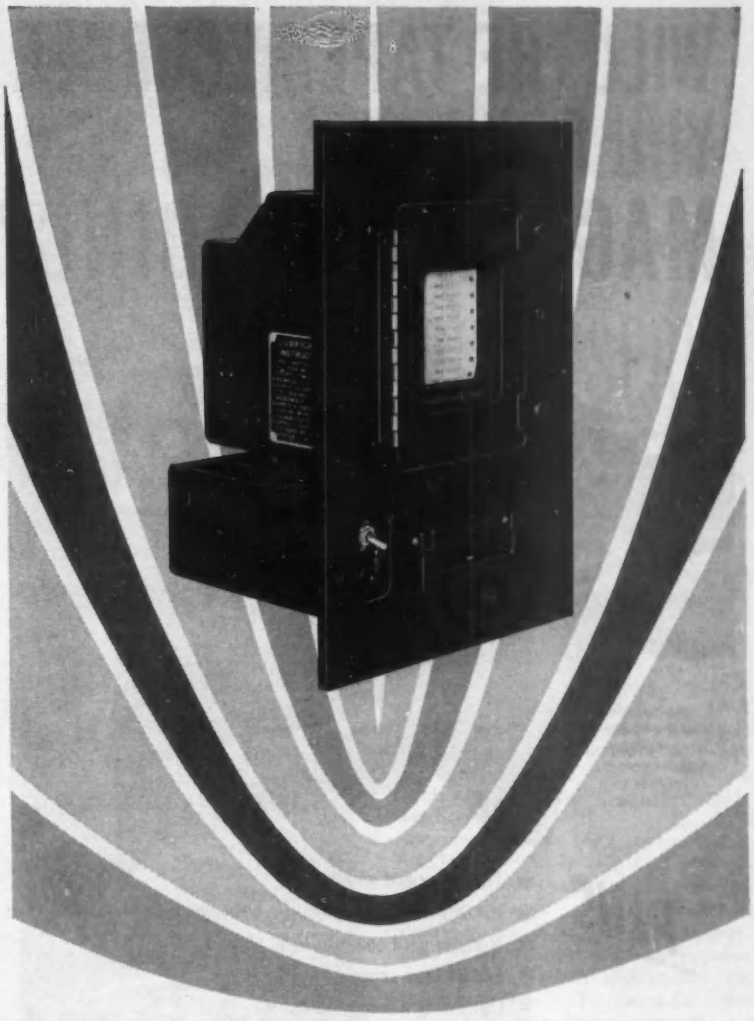


NEW CLARY MILITARIZED PRINTER

WITHSTANDS 50G SHOCK!

The new Model 2000 series printers designed by Clary will print digital data even under the extreme environmental conditions encountered in military use • These rugged, reliable printers are constructed on a sturdy panel for vertical rack mounting, and contain all necessary electronic equipment for data decoding, digit selection, and control functions of the printer • They are designed to print the output from computers, digital voltmeters, shaft position transducers, electronic counters and digital clocks. In addition, they are ideal in industrial applications where continuous, unfailing operation is required • For complete information on how Clary Model 2000 series can help you, write today for Engineering Bulletin S-120 •

Clary

Electronics Division
San Gabriel, California

CIRCLE 185 ON READER-SERVICE CARD

WILL THE TAPE RECORDER YOU BUY HAVE MAGAZINE LOADING?

Installing the magazine on the PS-200. Complete magazine change requires only 5 seconds.

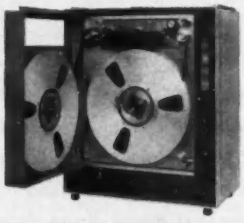
PLUS

* Transistorized electronics
* Up to 14 channels of record/reproduce
* Modular card construction
* End of tape sensing
* Light weight – only 65 lbs.
* Tape speeds 1⅞ to 60 ips

PS-200 FEATURES UNIQUE STACKED-REEL MAGAZINE.
Using 10½" standard NARTB or commercially available precision reels, the magazine is designed so that it can be completely removed from the transport or opened while still attached to the machine. No additional threading is required to change magazines. The magazine automatically locks in place, ready for operation with only five seconds interruption. Tape is in contact with heads in drive mode only. Head wear and oxide deposit are reduced.
The PS-200 can be quickly converted to a loop transport by simply exchanging the reel-to-reel magazine for a loop magazine.

The PS-200 instrumentation magnetic tape recorder combines transistorized electronics with a stacked reel tape magazine. Result – 10 to 1 weight, size, and power reduction with no degradation in flexibility or performance. Recording characteristics, tape speeds, and all other parameters of the PS-200 are completely compatible with standard recording practices.

Twenty-eight sales engineering representative offices are located throughout the United States and Canada to assist you with your data recording problems. For his name and free copy of new 8-page brochure, please write, call or wire Dept. C9.



Model PS-200 with magazine open. Note stacked reel construction.

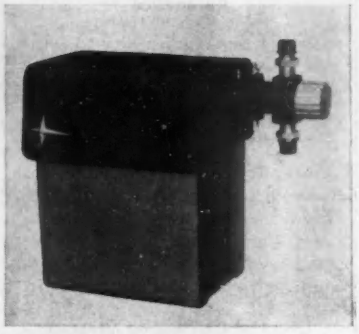
PRECISION INSTRUMENT COMPANY
1011 COMMERCIAL STREET, SAN CARLOS, CALIFORNIA • PHONE: LYTELL 1-4441

CIRCLE 186 ON READER-SERVICE CARD

NEW PRODUCTS

stem. When signal pressure drops, compression of the trapped air returns the valve to its normal position. –George W. Dahl Co., Inc., Bristol, R. I.

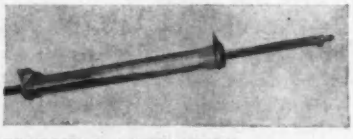
Circle No. 326 on reply card



ADJUSTABLE STROKE

Adjusting the stroke of this Model 1107 plunger-type proportioning pump provides feed rates of from 0.2 to 2.0 gph against discharge pressures as high as 300 psi. Designed for low-cost injection of chemicals into process streams, the pump operates on 110 volts and features a built-in reduction gear box and overload protection.– B-I-F Industries, Inc., Providence, R. I.

Circle No. 327 on reply card



VALVE & ACTUATOR

Shown here is the new HPA100100 linear servovalve and actuator combination. It consists of a cylinder, a piston, an input rod, and an output rod. Both rods are tubular and are connected to the piston, but the input rod has an inner sleeve capable of a slight motion relative to the outer sleeve. This motion is used to stroke a servovalve which is built into the piston head. Depending on the direction in which the input rod is moved, the servovalve directs the flow of the hydraulic fluid to one end of the cylinder or the other. Designed to operate with supply pressures up to 3,000 psi, this particular model has a 4-in. ID and a 30-in. stroke. Supply and

HIGH SPEED, Sensitive Polarized RELAYS

"DIAMOND H"

SERIES P
Relays

For electronic and communications applications

Engineered to provide extremely fast action with high sensitivity, freedom from bounce and excellent stability, "Diamond H" Series P Polarized Relays give consistent performance with low distortion. Under some conditions they will handle over 1,000 pulses per second.

Magnetically latched SPDT, with two independent coils, Series P Relays are available with various coil resistances from 10 to 4,000 ohms each coil. Contact ratings will vary with switching speeds desired, but range from 60 milliamperes to 2 amperes.

Extremely compact, to save space and weight, they fit standard octal sockets. Their impact and vibration resistance is excellent for relays of this type, thanks to extra-rugged construction.

"Diamond H" engineers are prepared to work out a variation to meet your specific requirements. Write or phone us your needs.

THE HART
MANUFACTURING COMPANY
165 Bartholomew Avenue
Hartford, Conn.

CIRCLE 187 ON READER-SERVICE CARD

BUILD ON... Eastern CONTROL EXPERIENCE:

SERVO SYSTEMS

Typical assignment: design and develop a missile elevon control servo with a single hydraulic power supply and three actuators. Weight and space considerations critical.

Solution: a system designed and built around the Eastern E/HS 5 type 100A hydraulic power supply, using a 400-cycle motor. Minus motor, but including pump, reservoir, expansion chamber, pressure regulating valve and filter, the supply weighs only 2.6 lbs.

Eastern achieved a 20% saving in hydraulic power supply capacity by the use of one of its own *pulse length modulated* single-stage servo valves, manifolded to each actuator. Zero first stage leakage, zero hysteresis, plus the high response and efficiency which characterize this valve contributed to the successful meeting of the demanding requirements.

Specifications:
force level: 300 lbs.
total stroke: 1/2 in.
max. velocity: 1.5 in./sec.
time constant: 0.1 sec.
max. actuator width: 1.25 in.

For genuine contributions to the solution of your servo problems, call in the Eastern engineer.

servo-valves • fuel controls • actuators

EASTERN INDUSTRIES INCORPORATED
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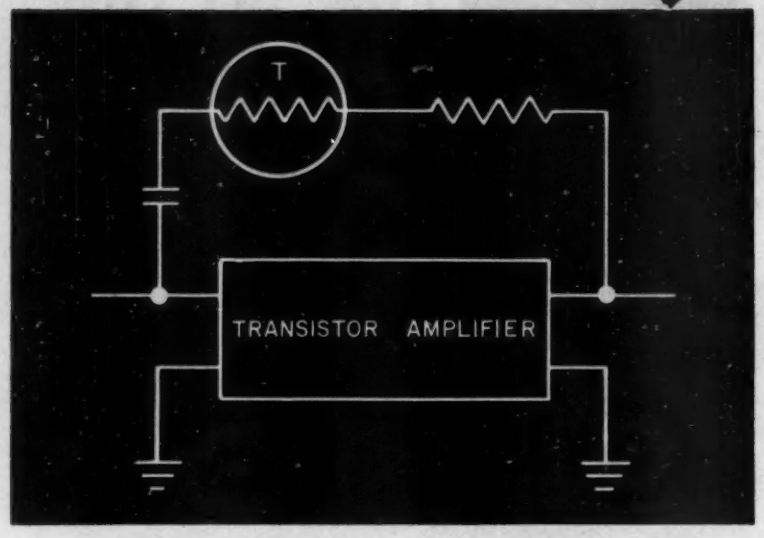
Eastern AVIATION PRODUCTS

CIRCLE 188 ON READER-SERVICE CARD

GLENNITE® THERMISTOR DESIGN IDEAS NO. 8



HOW TO KEEP POWER GAIN CONSTANT ON TRANSISTORIZED AMPLIFIERS

Maintaining constant power gain on transistorized amplifiers has always been a problem for computer design engineers. Recent work with Glennite Thermistors has provided a simple yet effective solution.

Glennite Thermistors are temperature-sensitive resistors with high *negative* coefficients of resistance. When a temperature increase in the amplifier circuit above causes increase in power gain, a wafer type thermistor in feedback circuit serves to maintain constant power gain.

The *negative* temperature coefficient of the thermistor results in decreased resistance as temperature increases. The resulting degenerative feedback compensates for power gain, maintains constant voltage output.

Transistor gain control in computers is only one of many interesting ways in which versatile Glennite Thermistors are used as economical solutions to problems of temperature control, time delay, measurements and analyses.

Glennite wafer, bead and rod thermistors are available in a variety of resistance values, temperature coefficients and sizes to help you evaluate circuit problems. They may be obtained from your local distributor, or from Gulton Industries in bulk quantities.

Test Your Ideas With A Glennite Experimenter's Thermistor Kit

An inquiry on your company letterhead will make available to you a Glennite Experimenter's Kit for $14.95. For those engineers who have had some experience with thermistors, comprehensive kits are available for $49.95. For complete information, write directly to Gulton Industries, Inc.

Custom Made Thermistors To Your Specifications

Gulton will supply thermistors to your specifications with resistance values from 1 ohm to 10 megohms and temperature coefficients of resistance to −6.8% per degree C. Temperature range: −60° to +500°C.

MATERIALS & CERAMICS DIVISION

Gulton Industries, Inc.

Metuchen, New Jersey

In Canada: Titania Electric Corp. of Canada Ltd., Gananoque, Ont.

CIRCLE 189 ON READER-SERVICE CARD

discharge ports are located at the ends of the rods.—Hydra-Power Corp., New Rochelle, N. Y.

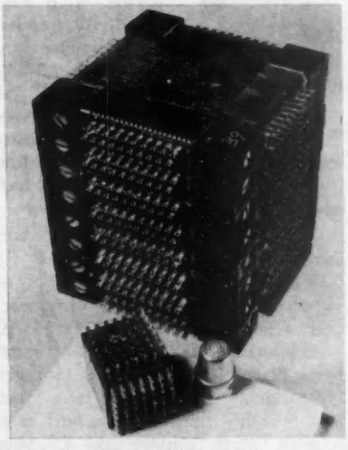
Circle No. 328 on reply card

PLUS. . . .

(329) A series of small, low-cost air valves for service on vacuum or air pressures to 300 psi has been developed by **Numatics, Inc.**, Highland, Mich. . . . (330) **Barber-Colman Co.**, Rockford, Ill., now manufactures a complete line of 1¼-in. diameter permanent magnet **dc motors** in three different frame lengths. . . . (331) The L3 Series of high-flow, three-way **solenoid valves**, announced by **Skinner Electric Valve Div.**, New Britain, Conn., are designed to operate on pressure differentials of from 5 to 150 psi.

Circle No. 329, 330, or 331 on reply card

COMPONENT PARTS



TINY MEMORY STACK

Physical volume of this new miniaturized memory stack is about 1/50th the volume required for a conventional stack. Designed for coincident current systems, the unit has a ferrite core density of about 3.5 million cores per cu ft. Other advantages of the new design include shorter lead lengths and fewer solder connections.—Applied Logics Div., General Ceramics Corp., Keasbey, N. J.

Circle No. 332 on reply card

are you spending $12.00 for a one cent job?

If you're duplicating drawing details, you're squandering precious hours of costly drafting time. STANPAT, the unique tri-acetate that is pre-printed with your standard and repetitive blueprint items, cuts time involved from 3 hours to 15 seconds! Figured at current pay rates, this means a $12 job at less than one cent . . . the STANPAT way. Easily transferred to your tracings by an adhesive back or front, STANPAT relieves your engineer of time-consuming and tedious details, freeing him to concentrate on more creative work.

here's how simple the STANPAT method is!

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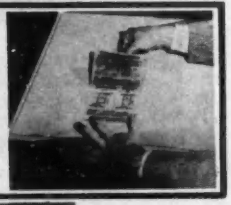

PLACE the STANPAT into position on the tracing.

PRESS into position . . . will not wrinkle or come off.

STANPAT is available in two types of adhesive backs:

- Rubber base for standard drafting and tracing papers
- Resin base to prevent leaching for papers that contain oils

But whatever the application may be, there's a STANPAT product for your specific needs. STANPAT has a guaranteed shelf life of one year from date appearing on tab end. For further information and technical assistance, complete the coupon below and mail.

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Phone: FLushing 9-1693-1611

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GUARDIAN

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1623-K W. WALNUT STREET, CHICAGO 12, ILLINOIS

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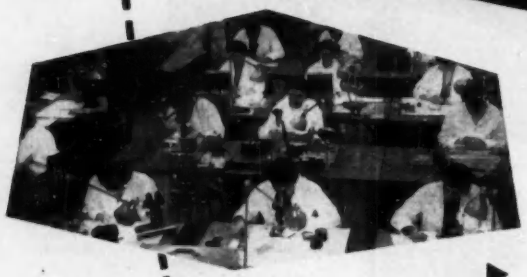
PRECISION POTENTIOMETERS



With all due apologies to Topsy of Uncle Tom's Cabin, that is. But growed we have . . . until today Kintronic possesses one of the most complete facilities for the production of potentiometers. Equipment, engineers, assemblers, quality control standards that add up to development and manufacture of precision potentiometers for every requirement. An almost unlimited variety of pots designed to accurately function under the severest of conditions.

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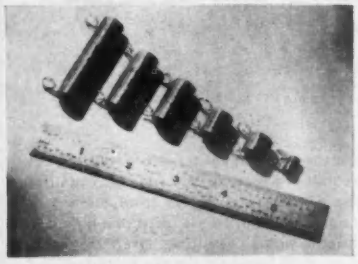
NEW PRODUCTS



PRECISION RESISTORS

Available in approximately 40 sizes and wattages, the new line of Delta-Ohm precision wire-wound resistors features a resistance tolerance of 0.005 percent in experimental quantities, and an operating temperature range from minus 65 to plus 135 deg C. Insulated aluminum bobbins improve mounting flexibility and eliminate the danger of hot spots.—Leonard Electronics, Montebello, Calif.

Circle No. 333 on reply card

RADIATION RESISTANT

According to its manufacturer, this Size 15 servomotor, Model T175-001, operates effectively at temperatures ranging from minus 54 to plus 200 deg C, and will withstand up to 10 billion roentgens of radiation.

Characteristics:

No-load speed: 5,000 rpm, min
Stall torque: 1.45 oz-in.
Weight: 7.3 oz
Fixed phase voltage: 115 volts
Power input: 6.1 watts per phase
Frequency: 400 cps
—Kearfott Co., Inc., Clifton, N. J.

Circle No. 334 on reply card

FLEXIBLE AMPLIFIER

The Model D-7 Airborne Amplifier, designed for thermocouple and strain gage amplification and telemetering applications, is a differential, high-gain unit that will operate to critical specifications from a variety of power inputs and over broad temperature,

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CIRCLE 193 ON READER-SERVICE CARD

ROTARY multi-pole multi-circuit SWITCHES

TYPE **JL**

TYPE **MA-12**

FOR ELECTRIC CIRCUITS:

TYPE JL rotary switch is a low-power switch with an electrical rating of 5 amperes, 125 volts a-c. A maximum of eight positions — up to ten sections — are controlled by a single knob. This type permits unlimited rotation in both directions but can be limited to any number up to eight positions by two stop screws. It is designed for single-hole panel mounting. Meets MIL-S-21604 and BuShips Drawing Number 9000-S6202-74422. Write for free Bulletin 101-A containing comprehensive data.

FOR ELECTRONIC CIRCUITS:

TYPE MA-12 is a miniature rotary switch with an electrical rating of 3 amperes, 115 volts a-c. A maximum of six contact positions — up to five sections — are controlled by a single knob mounted on a ¼" shaft. Rotation can be unlimited in both directions but can be limited from two to twelve positions by two stop screws. This type rotary switch mounts in ¾" square, single-hole panel mounting. Designed to meet MIL-S-3786.

ESCO has a broad line of other standard rotary switches with electrical ratings up to 200 amperes. Parts of these standard switches may be assembled in a different manner in order to meet unusual or highly specialized circuit control requirements. These special combinations may comply with BuShips Drawings and MIL-Specifications. Write for Bulletin 8-A giving detailed information.

ESCO of WEYMOUTH
ELECTRO SWITCH CORPORATION
167 King Avenue, Weymouth 88, Massachusetts

CIRCLE 194 ON READER-SERVICE CARD

ONLY *wiancko offers a portable secondary standard with digital readout*

Check these exclusive features:

- ☑ Permits direct parameter measurements and calibration of transducers (pressure, force and accelerometers) in field, plant or laboratory.
- ☑ x2 and x4 plug-in frequency multiplier, coupled with bandwidth adjust provides greater accuracy due to increased resolution and real data capability — speedier testing and checkout.
- ☑ Readily interchangeable plug-in units for absolute, gage and differential pressure heads — ranges 5 to 10,000 psi.
- ☑ Head adapter permits use of Wiancko force rings, accelerometer or pressure pickups — 500 feet distant from Standard.

Accuracy: ±0.05 percent full scale; ranges 0-2500 psi
±0.08 percent full scale; ranges 3000-10,000 psi

For more information write for Product Bulletin 106A.

WIANCKO
ENGINEERING COMPANY

255 North Halstead Avenue • Pasadena, California

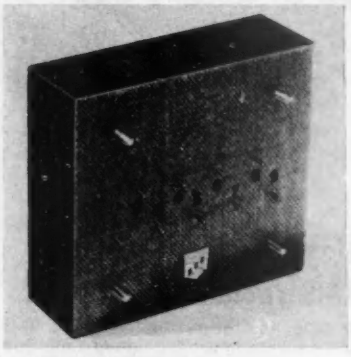
CIRCLE 195 ON READER-SERVICE CARD

NEW PRODUCTS

altitude, and vibration ranges.

Characteristics:
Input level: plus or minus 5 mvdc
Input impedance: over 20 K
Gain: 400 to 1,000
Bandwidth: dc to 1,000 cps
Power required: about 25 ma at 28 vdc or 55 ma at 6.3 vac, 400 cycle—Southwestern Industrial Electronics Co., Houston, Tex.

Circle No. 335 on reply card



FOUR-IN-ONE

The Model 71-30 ESC Delay Line actually contains four separate delay lines, each with a 1.0-μsec delay and a 1,000-ohm characteristic impedance. The entire unit is encased in molded epoxy and has a glass melamine terminal board with gold-plated pins. Designed for printed circuit applications, it is particularly suitable for dip soldering techniques. Unit measures 3 by $2\frac{7}{8}$ by 1 in. thick.—ESC Corp., Palisades Park, N. J.

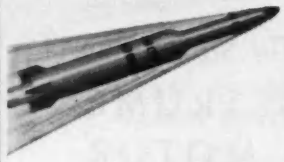
Circle No. 336 on reply card

PLUS. . . .

(337) **General Transistor Corp.**, Jamaica, N. Y., has a new line of "bobbinless" precision **wire-wound resistors** with truly strain-free resistive elements. . . .(338) A do-it-yourself **transformer,** developed by the **Superior Electric Co.,** Bristol, Conn., consists of a self-contained toroidal coil that serves as a primary in ac voltage source applications or as a secondary in current transformer applications. . . . (339) A complete line of subminiature transistorized **amplifier assemblies,** suitable for a variety of missile system, computer, and control applications, was recently announced by **Reeves Instrument Corp.**, Garden City, N. Y.

Circle No. 337, 338, or 339 on reply card

ELECTRONICS: Over, on and under...



INTERESTED IN TRANSISTOR CIRCUITRY?

Here's the challenge at Autonetics—can you develop *original techniques* in transistor circuitry, from either a component or systems level, for any or all of the following systems:

Inertial Guidance

Radar Armament Controls

Flight Controls

Automatic Checkout Centrals

Production Test Equipment

Digital Computers

If you have a BSEE and several years of design, research, development or test experience in transistor circuitry, you can pick your field and share in the many "first" achievements of Autonetics young engineers.

In addition, we'll provide financial support for advanced education at the many fine universities in our area.

Send your resume to:
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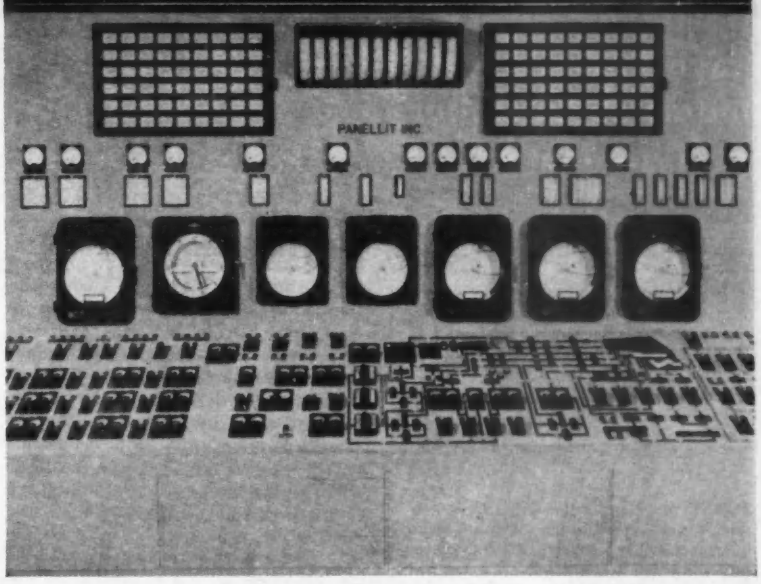

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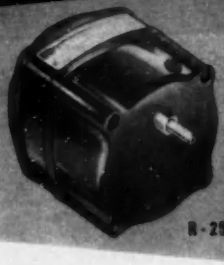
CIRCLE 196 ON READER-SERVICE CARD

HOLTZER -CABOT

R-24 Motor

Synchronous and Induction Capacitor Type Motors



R-25 Motor

R-24. Typical applications for this reversible, 4-pole induction motor are in servo mechanisms, as a balancing motor in recording instruments or as a control motor for voltage regulators. It has low rotor inertia for fast response applications. When operated 2 phase, it can be controlled electronically; or operated single phase as a permanent split capacitor motor.

R-25. Typical uses are for recording instruments, dictating and adding machines. Approximately 2½" in diameter, it is available in either induction or synchronous construction with reversible rotation.

Both the R-24 and R-25 are available with gear case speeds from 1/2 to 3600 RPM, torque ratings up to 75 oz. inches or higher, and single phase, 2 or 3 phase.

HOLTZER-CABOT MOTOR DIVISION
NATIONAL PNEUMATIC CO., INC.
125 Amory Street, Boston 19, Mass.

GENTLEMEN: Please send me data sheets on the Holtzer-Cabot R-24 and R-25 Size Motors.

Please have representative call _____ (date)

Name _____

Company _____

Street _____

City _____ Zone ____ State _____

CIRCLE 197 ON READER-SERVICE CARD

WHAT'S NEW

(Continued from page 51)

analyzing data, the Ortholog Div. will also enter into the design and development of instruments for performing these functions. Production is expected soon on spectrum analyzers, amplitude analyzers, and airborne transient timers.

This tenth of the Gulton companies and subsidiaries will be headed by Arthur S. Westneat and Dr. A. G. Ratz. The new group, formed in Metuchen, N. J., is expected to enable Gulton to offer an integrated systems concept, giving it capabilities to provide anything from individual components to complete instrumentation systems.

Fischer & Porter Plans Own Fiberglass Production

Warminister Fiberglass Co. is the name of an autonomous company formed by Fischer & Porter, Hatboro, Pa., control manufacturer in a rather unique diversification move. The new company, located next door to its parent, will furnish all reinforced plastic parts required by F. & P. and will also solicit outside business. Robert Tomlinson, an F. & P. man, is manager of the organization.

General Controls Organizes To Handle Systems

General Controls Co. has organized a new Electronic Systems Div. to handle complete electronic systems such as General Controls' air data, altitude, and Mach number computers. The company's electronic controls div. will continue to produce only components including valves, pressure switches, actuators, and potentiometers. The move resulted from continued growth in the magnitude and complexity of the electronic systems portion of General's operations. Fred Marsh, the company's engineering manager, moves up to general manager of the systems division, to be located in Glendale, Calif.

New Servo Company Steers From Systems Approach

A new company in the design, development, and production of servo components is the Vernitron Corp., with manufacturing facilities in Torrance, Calif., and offices and research and development activities in New York City. Plans call for the company

(Advertisement)

The Second Annual
INSTRUMENT MOTOR SYMPOSIUM
sponsored by
Holtzer-Cabot Motor Division
National Pneumatic Co., Inc.

will be held in Chicago during the week of the ISA Instrument-Automation Conference and Exhibit.

Theme: "Today's Trends — Tomorrow's Motors"

Speakers: Nationally-known instrument and motor design specialists. Open discussion will follow the prepared remarks.

When: 8:00-10:00 p.m., Tuesday, September 22.

Where: Palmer House, Chicago

How to Register: Members and guests of the ISA may register at Holtzer-Cabot's exhibit (#368) at the International Amphitheatre on Monday or Tuesday or by writing earlier to the Symposium Chairman: R. H. Matthews, Chief Engineer, Holtzer-Cabot Motor Division, National Pneumatic Co., Inc., 125 Amory Street, Boston, Massachusetts.

CIRCLE 198 ON READER-SERVICE CARD

FREQUENCY RESPONSE for PROCESS CONTROL

JUST OUT! A clear presentation of the fundamental methods of frequency response and their application to the analysis, testing, and design of process control systems. Thoroughly explains the analysis of complete systems by means of highly effective techniques, and gives typical solutions to many practical problems. By 9 Specialists. **Edited by W. I. Caldwell,** Dir. of Research, Taylor Instruments Co., **G. A. Coon,** Dept. of Math., Univ. of Conn., and **L. M. Zoss,** Asst. Prof. of Mech. Engrg., Valparaiso Univ. **395 pp., 267 illus., $11.50**

RADIATION HYGIENE HANDBOOK

JUST OUT! A practical reference covering the industrial, medical, and research uses of radiation and atomic energy, with data and methods for measuring radiation, and for protecting persons and property from radiation hazards. Offers a vast array of essential information on exposure standards, sources of radiation, waste disposal, air and water pollution control, physiological effects of radiation, etc. **Edited by H. Blatz,** formerly A.E.C. Health and Safety Laboratory. **650 pp., 250 illus., $27.50**

ELECTRONIC SWITCHING, TIMING, AND PULSE CIRCUITS

JUST OUT! New, integrated treatment of analytical techniques for dealing with electronic circuits in which tubes and transistors are used primarily as switches, and resulting waveforms may be rectangular, triangular, or a succession of short pulses. **By J. M. Pettit,** Assoc. Prof. of Elec. Engg., Stanford Univ., **250 pp., 223 illus., $7.50**

DIGITAL COMPUTER PRIMER

JUST OUT! Gives a concise explanation of modern digital computers, describing how they work, what they can do, and their important mathematical, engineering, electronic, and accounting aspects. All topics discussed in non-specialist's language. **By E. M. McCormick,** Head, Data Assessment Div., U. S. Naval Ordnance Lab. **205 pp., 63 illus., $7.50**

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Typical Control Functions solved by AIR CIRCUITRY

WESTINGHOUSE "H" CONTROLAIR® VALVES

Air control valves are not limited to directional control in Westinghouse Air Brake Company's complete line of Air Circuitry components. Pressure control, in addition to directional control, is obtained with the versatile "H" CONTROLAIR Valves. The position of its operator—lever, pedal, cam or knob—determines the air pressure delivered by the valve. Changing operator positions changes delivery pressure.

Precise pressure graduations may be made in one or two outlets to provide exacting remote control of variable force and positioning applications. Besides those functions illustrated a wide variety of pressure and directional control combinations is available. For details, ask for Catalog D4-65.00.

Applications for "H" CONTROLAIR Valves are limitless. They operate:

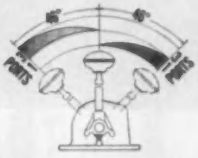
Throttles	Rolling Mills	Marine Propulsion Engines
Clutches	Presses	Construction Equipment
Brakes	Shears	Oil Drilling Rigs
Clamps	Conveyors	Production Tools
Gates	Dredges	Cranes and Shovels

and many other kinds of equipment and machines. In fact, "H" CONTROLAIR Valves are used wherever it is necessary, or preferable, to have instant and convenient control of the flow of air into a pneumatic circuit and of the pressure build up of air in that circuit.

What is AIR CIRCUITRY?

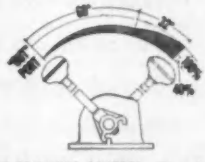
This is the Westinghouse term for application of pneumatic control systems to industrial production operations. Safe, economical, precise AIR CIRCUITRY is now being used to solve the most rigorous and complex control problems in industry. Westinghouse Air Brake has pioneered the application and development of air control for more than 80 years. Today our engineers can design an air circuit which will help you boost production and cut costs in your plant or shop.

1. SINGLE LINE PRESSURE CONTROL—Pressure regulation in a single line is obtained through the H-2 CONTROLAIR Valve. This lever-operated, 3-way, pressure regulating valve increases, decreases or maintains outlet pressure according to its lever position. Several types of lever return or holding functions are available.



2. DIRECTIONAL PRESSURE CONTROL—The HC-2 CONTROLAIR Valve provides pressure graduation to either of two outlets. This lever-operated 4-way, pressure regulating directional valve consists of two 3-way directional valves and a 3-way pressure regulating portion. Lever movement either side of its "Neutral" position selects the outlet to be activated. Further lever movement in the same direction controls the pressure of the air delivered to that line.

3. DIRECTIONAL AND PRESSURE CONTROL—Pressure regulation plus full supply pressure directional control is possible with the HD-2 CONTROLAIR Valve. This lever-operated valve consists of two 3-way directional valves and a 3-way pressure regulating position. Each unit has its own outlet. Lever movement either side of "Neutral" provides full inlet pressure to a chosen outlet plus graduated pressure to a third outlet.



4. TWO RATE PRESSURE CONTROL—The first 60° of lever movement from the "Off" position provides an increase in delivery pressure from 0 to 40% of maximum value in the H-2-E type CONTROLAIR Valve. The remaining 32° of lever movement increases from 40% to its maximum value. Used in applications that require closer pressure adjustment at the low end of the delivery pressure range than at the high pressure end of the range.

See the Yellow Pages under Cylinders for the Name of Your Local Distributor

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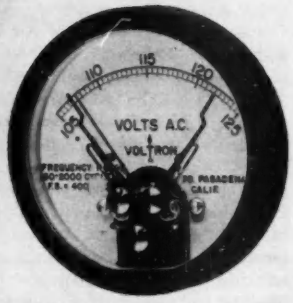

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Assembly Products, Inc.
Chesterland, Ohio

VOLTRON
VOLTRON PRODUCTS
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WHAT'S NEW

to design and build synchros, resolvers, servo motors, and tachometers without being involved directly with complete systems or assemblies in which they would be used.

Vernitron's president is Bernard Levine, long associated with Ketay and also with Bendix and the Atomic Energy Commission. Julian Spector is vice-president in charge of engineering. He has experience with Kearfott, Arma, and Ketay. Sales vice-president is Harold M. Winton, whose background includes U. S. Rubber, GE, and Ketay and teaching at City College of N. Y. and N. Y. University.

Other New Companies and Divisions

The Industrial Div. of Moog Servocontrols, Inc., to develop the company's industrial product line, handle non-military marketing activities, and extend commercial business—in East Aurora, N. Y. Division manager will be Harvard B. Kolm. With Moog for several years, he came from Minneapolis-Honeywell's Aeronautical Div.

A ground support equipment and test div. of Century Electronics & Instruments, Inc., to furnish airlines, airframe and missile manufacturers, and the military with ground support and testing prototypes and production equipment—in Tulsa, Okla. The new organization will be located in the facilities of the Aviation Div. of Spartan Aircraft Co. Century has an arrangement with Spartan to handle joint research and development programs, service, and production.

The **Space Technology Div.** of Aerojet-General Corp., to perform research and development in advanced propulsion systems, space systems, and various other areas of space technology —in Azusa, Calif. In setting up the division, the General Tire and Rubber Co. subsidiary named Y. C. Lee as manager.

An **astronuclear laboratory** as a part of a new Westinghouse atomic power division, to develop nuclear energy for outer space—in Pittsburgh, Pa. The new division will include the existing activities of the company in the development of commercial apaplications of atomic energy for electric power generation.

Head of the new division will be John W. Simpson, a vice-president formerly in charge of the Bettis

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B.S.–M.E. or E.E.: You have 5+ years experience in ground radar; design and detail experience is desirable.

B.S.–E.E.: You have 5-10 years experience in field engineering, component and systems development, and field and flight evaluation.

Direct your inquiry to Mr. C. T. Petrie, 336 North Foothill Road, Beverly Hills, Calif.

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Electronic Equipments Division

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WHAT'S NEW

Atomic Power Laboratory which Westinghouse operates for the Atomic Energy Commission. Dr. Sidney Krasik will be technical director of the astronuclear lab.

Raytheon To Buy Sorensen In $3-Million Stock Deal

The Raytheon Co. has made arrangements to purchase Sorenson & Co., Inc., well-established controlled-power supply manufacturer. Sorenson will retain its present name and organization and will become a subdivision of Raytheon's Industrial apparatus Division as a wholly-owned subsidiary. The price for the South Norwalk, Conn., and New York City firm was less than $3,000,000 in Raytheon stock—one-third cumulative preferred, the rest common.

Sorenson was founded in 1942 by the late Edward M. Sorensen and is presently privately owned by President Albert H. Blanc and board chairman Marcel Corbat. Leo L. Helternine, Jr., executive vice-president and general manager, will continue to run the organization.

The acquisition follows up the recent merger (CtE, May '59, p. 58) of Machlett Laboratories into Raytheon and is part of the Waltham, Mass., firm's newly announced plan to broaden its commercial base.

$50-Million Merger Joins Electronics, Utility Corps.

Moves for the consolidation of $50-million worth of electronics, utility, and pharmaceutical concerns in an interesting combination of maker and user have begun with the result, yet to be stockholder-approved, to yield a new company, the Consolidated Electronics Industries Corp. Participants in the consolidation operation are Central Public Utility Corp., which operates transportation services in the U. S. and utilities overseas, Consolidated Electronics Industries Corp. (not the same as the new resulting company), Philips Industries, Inc., Philips Electronics, Inc. (the three latter being electrical and electronic equipment manufacturers), and Anchor Serum Co.

Actually, the way it will work is this: Con Electron will be the new top company. It will continue the operations formerly conducted by Central Public, the old Con Electron, Philips Industries, and Philips Elec-

tronics (64 percent owned by Philips Industries). Besides these, Advance Transformer decided to join the old Con Electron before the other mergers were worked out.

Anchor Serum Co., the largest independent U. S. manufacturer of animal vaccines, will merge into the Islands Gas and Electric Co., which will be 100 percent owned by Con Electron. From this merger will result a company to be known as Philips Electronics and Pharmaceutical Industries, Inc., 66 percent owned by the top company. The operations of PE&PI will also include Philips Roxan, Inc., which has formerly conducted the drug distributing activities of Philips Industries, Inc.

With the merger completed, the combine will be worth about $50-million with annual sales and revenues estimated at $90-million. PE&PI alone is worth $27-million, and consolidated sales should be about $30-million. Central Public stockholders will exchange their shares on a one-for-one basis, old Con Electron shareholders on a basis of 1.25 shares for one presently held. In the formation of PE&PI, Philips Electronics owners will exchange share for share.

Other Acquisitions

The Cross Co., Detroit machinery builder, has acquired Stephen F. Malaker Associates as a new subsidiary, Cross-Malaker Laboratories, to work in the field of combining atomic energy techniques with electronics and using them in instrumentation.

Automation Instruments, Inc. has purchased Mid-Continent Manufacturing, Inc., adding this manufacturer of structural components and electronic and electro-mechanical products and leaser of industrial equipment to AI's ultrasonic testing line (see also CtE, April '59, p. 62). The deal involved exchanging 500,000 common shares of AI for the outstanding stock of Mid-Continent.

Comptometer Corp. has diversified into the electronics and instrumentation field by acquiring Radiation Electronics Corp. The new division will continue to manufacture infrared detectors, remote temperature instruments, thermal imaging devices, and high speed infrared scanning units.

Topp Industries, Inc. has acquired U. S. Semiconductor Products, Inc. for 66,758 shares of Topp common stock and $2,800. U. S. Semcor will be a division of Topp, manufacturing diodes, capacitors, other semicon-

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BALLISTIC MISSILES
Actual Size
Among the hundreds of vital parts required for ballistic missiles are several KLIXON Hermetically Sealed Thermostats. Spencer Division supplies thermostats to the General Electric Company's Missile and Ordnance Systems Department, developers of the nose cone for the Air Force's THOR IRBM.
KLIXON snap-acting controls are ideal for applications of this type — for several important reasons. They are small in size and light in weight; they respond to temperature change quickly and with accurate repeat performance; they have ample capacity to handle heavy electrical loads; and their calibrations stand up in the face of severe environmental conditions.
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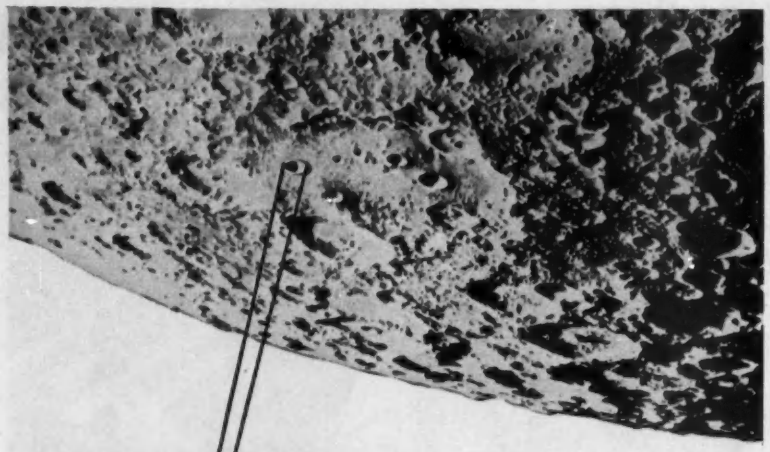


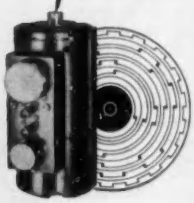
Sensing .001° angular displacement—

NORDEN'S BRL-5 ANGLE ENCODER

A 4¼-mile crater on the moon, or a table tennis ball at a distance of a mile—these are examples of the extraordinarily acute .001 degree angular displacement which can be sensed and encoded by the BRL-5 Precision Angle Encoding System.

The system is made up of a small, light transducer and an associated electronic encoder which converts angular data into digital language. The transducer is less than ⅛ the size of other angle encoding devices having lower resolutions. Three and three-eighths inches in diameter, it weighs only 5 lbs. 6 oz.

The transducer features a unique capacitive averaging technique. Accuracy depends on the precision with which the phase of two AC signals represents the relative angle between two stators. Since each signal is generated by the simultaneous action of 360 finely engraved serrations, with any inaccuracies averaged out over 360 samples, exceptional precision is assured.



First made for optical instruments such as the BALLISTIC RESEARCH LABORATORY'S Space Probe Optical Recording Telescope (SPORT), the BRL-5 has many potential uses. These include missile launching platform positioning, machine tool rotary table indexing, stable platforms, missile test range data acquisition, and air-borne instrumentation.

Produced in cooperation with Colorado Research Corporation, of Denver, the BRL-5 is another example of Norden's engineering excellence. Write, or call TRinity 4-6721, for complete data or engineering consultation.

NORDEN Division of United Aircraft Corporation

Milford Department, Wiley Street, Milford, Connecticut

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ductor devices, and silicon materials for infrared applications (see also CtE, April '59, p. 60).

Now It's

Waldorf Electronics of Huntington, N. Y., formerly the Electronics Div. of Waldorf Instrument Co. Name change marks change to full corporate division status for the company owned by F. C. Huyck & Sons.

The Fostoria Corp. of Fostoria, Ohio, representing the combined name of the former Fostoria Pressed Steel Corp., Chempump Corp., and Zenith Engineering Corp.

IMPORTANT MOVES BY KEY PEOPLE

Instrument Men Join NEMA, Other Groups Name Officers

Electrical instrument manufacturers have affiliated with National Electrical Manufacturers Assn. as a new industry section. The scope of the instruments involved includes all those "wherein a pointer is made to move over a calibrated scale, such movement being effected by the action of electric current and/or voltage". The new section also named officers including W. H. Steinkamp, vice-president, Daystrom Inc.-Weston Instruments Div., as chairman and J. R. Whiteside, president, Simpson Electric Co., vice-chairman.

The new section has already started a statistical survey to collect information on open dollar market sales and unit production in its product field and has held a conference with the Business Defense Services Administration to discuss industry-government cooperation. A technical committee will work with American Standard Assn. to develop new standards for electrical indicating instruments.

Another NEMA section, Motor and Generator, elected R. G. Liebmann, Commercial Manager, U.S. Electrical Motors, Inc., as its new chairman. He succeeds W. H. Kingsley who resigned recently as Sales Manager of the Electrical Div. of Fairbanks, Morse & Co. Other officers of the section remain unchanged.

In other societies elections, the Fluid Controls Institute has named new officers which include James R. Lawler, Jr., of Lawler Automatic Con-

trols, Inc., president; Fred Weldon of General Controls Co., first vice-president; Robert McCormick of Automatic Switch Co., second vice-president; Paul Rogers Jr., of Skinner Chuck Co., treasurer; and Eric A. Bianchi of Mason-Neilan Div. of Worthington Corp., secretary.

Allen New Manager At GE Instrument Dept.

Raymond C. Allen has been appointed manager of engineering at GE's Instrument Dept. in West Lynn, Mass. Allen joined GE in 1942 as a test engineer and has been at the Instrument Dept. since 1947, starting as a technical engineer. He has held positions of manager of process instrument engineering, instrument project manager, and most recently, manager of the industrial instrumentation section.

LEAD Names Batdorf To Head Research

Lockheed Electronics and Avionics Div. has appointed Dr. Samuel B. Batdorf director of research. Dr. Batdorf recently served as an assistant to Advanced Research Projects Agency chief, Roy P. Johnson, as head of a technical team responsible for military communication satellites. At the time, he was on leave from Lockheed's Missiles and Space Div.

Dr. Batdorf joined Lockheed in 1956 and went to the Pentagon two years later. Previously he had been a development director for Westinghouse and had worked for eight years in structures research for the National Advisory Committee for Aeronautics.

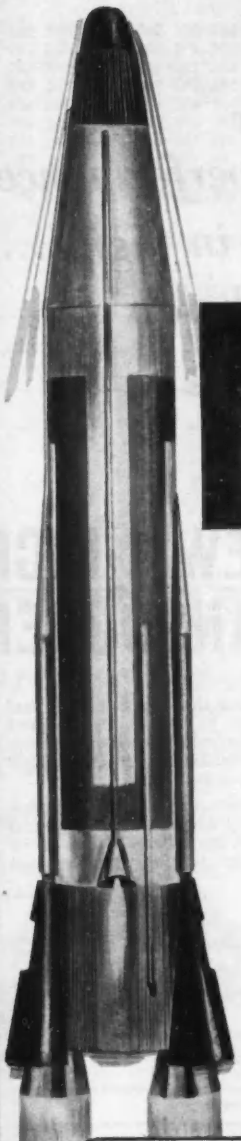
Barnes Elected V. P. At Waldorf Electronics

C. Brooks Barnes, new vice-president and general manager at Waldorf Electronics, will direct the company's development and production of airborne instruments, ground support equipment, training equipment, and servo components. Barnes comes to Waldorf after 12 years with Emerson Electric Manufacturing Co., where he has been project engineer, chief project engineer, assistant chief engineer, and head of the company's program control dept.

Rubel Leaves Hughes Lab. To Take DOD Post

The Department of Defense has appointed John H. Rubel assistant director of defense research and engineering for strategic weapons. Rubel will take a leave of absence from

Dependable when the going is tough!



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Hermetically sealed, miniature relays that combine compactness, dependability, ruggedness with minimum weight. Type M relays meet all critical military and commercial specifications.

Type M relays bring you all these features:

Heavy Duty Contacts
a—120 V. A.C.—10 amps, non-inductive
b—28 V. D.C.—5 amps, inductive
c—28 V. D.C.—10 amps, non-inductive

Rotary Action dynamically balanced armature

Special Contacts for dry circuit applications

Special Mountings available

Wide Variety of header types

Basic Dimensions
1¾" x 1" x 1-3/16" dia.
Contacts: ⅛" x ⅛" x .047".
Weight: 4 oz.

Write for full details. Kellogg will gladly design relays to meet your own specifications and operating conditions.

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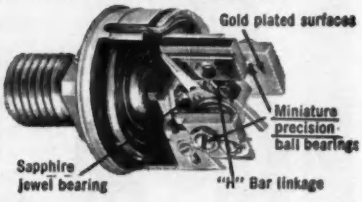
...as small as a bumble bee, but can take shock, acceleration and vibration like no other pressure transducer its size. It was designed specifically for airborne instrumentation to meet the most stringent environmental requirements. Output signal resolution is less than 0.25% with single or dual wire wound potentiometer pick-off.

The excellent performance under environmental conditions is due to an improved "H" bar linkage between the diaphragm push rod and the potentiometer wiper arm which permits the moveable parts to be statically and dynamically in balance under various vibrations and accelerations.

Fairchild's line of Pressure Transducers include bourdon tube and capsular diaphragm types for measuring pressures from 1 to 10,000 psi, absolute, gauge, or differential. Standard units have pot pick-offs; a.c. type pick-offs available on special order.



SPECIFICATIONS AND CHARACTERISTICS			
Vibration	10 to 55 cps, 0.1" da; 55 to 2,000 cps 15g. Error less than 1%. Will withstand 25g, 10 to 2,000 cps.	Pressure Range	0-5 psi to 0-350 psi a, g or d.
Acceleration	40g in 3 planes; error less than 1%. Withstands 75g.	Linearity	±1.0%
Shock	50g without damage or permanent calibration shift.	Size (Volume)	¾ cubic inch (1" dia x 1" long)
		Temperature	—54°C to +100°C. Error less than 1% for most ranges.

For more information write Fairchild Controls Corporation, Dept. 23C

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WHAT'S NEW

Hughes Aircraft Co., where he has been director of the airborne systems laboratory. He has 16 years' electronics experience and has been with Hughes since 1946, working in automatic celestial navigation, armament control, and other airborne systems.

J. K. Slap Named In Aeronutronic Promotion

Joseph K. Slap, author of this month's article, "Recording and Processing Test Data", has been promoted to manager of product planning for computer operations at Aeronutronics, a division of Ford Motor Co. Slap had been special assistant to the director of marketing for the computer group.

Prior to joining the Newport Beach (Calif.) firm, Slap was assistant general manager of the ALWAC Computer Div., El-Tronics, Inc. He also had been employed as a group engineer in charge of the electronic computing and mathematical analysis section, fluid dynamic dept. of Northrop Aircraft, Inc.

Other Important Moves

Thaddeus J. Kusto has been appointed director of research, and **Milton M. Gerber** has been named chief engineer at Computer Systems, Inc. Kusto, with 18 years experience in the field, comes from E. P. R. Special Products Corp., where he was executive vice-president. Gerber was senior project engineer at Reeves Instrument.

Dr. Robert E. Samuelson has been moved up to assistant general manager for research and development at Motorola's western electronics center. With Motorola since 1950, Dr. Samuelson has been senior project leader, chief engineer, and engineering manager of military electronics.

Edward G. Parsons will become chief engineer, and **Dixie B. McKey** has been named staff technical consultant at Milgo Electronic Corp. Parsons replaces **Monroe A. Miller** who had also been serving as president of the corporation. The latter will now devote more time to new products development. Parsons came to Milgo in 1955 from Sperry Gyroscope Co. McKey has 30 years experience in electronics and came to Milgo from the Philco Corp.

William J. Thayer has been appointed assistant chief engineer by Moog Servocontrols, Inc. Thayer did instrumentation development for Boe-

One of these handy prepaid post cards will bring you detailed information

IMPORTANT: Circle key numbers below and mail before December 1, 1959

	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
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5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195
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	208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
	209	219	229	239	249	259	269	279	289	299	309	319	329	339	349	359	369	379	389	399

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5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195
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	205	215	225	235	245	255	265	275	285	295	305	315	325	335	345	355	365	375	385	395
	206	216	226	236	246	256	266	276	286	296	306	316	326	336	346	356	366	376	386	396
	207	217	227	237	247	257	267	277	287	297	307	317	327	337	347	357	367	377	387	397
	208	218	228	238	248	258	268	278	288	298	308	318	328	338	348	358	368	378	388	398
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ing's flight test department and was a project engineer at Cornell Aeronautical Laboratories before joining Moog.

Gardner P. Wilson will head the newly created Western Engineering Div. of Brush Instruments, a division of the Clevite Corp. The new activity in the Los Angeles area will provide closer contact with west coast technological activities. Wilson joins Brush from the Electro-Data Div. of Burroughs Corp. and was also with Consolidated Electrodynamics Corp.

Raymond P. Lambeck has joined the Aero Hydraulics Div. of Vickers, Inc., Div. of Sperry Rand Corp., as engineering manager for major programs. Lambeck will head the section handling major contracts for new missile aircraft pumping and drive systems. He had been with the Hamilton Standard Div. of United Aircraft Corp. for 20 years.

Dr. James Wakelin has resigned as member of the board of directors of the Chesapeake Instrument Corp. to accept an appointment as Assistant Secretary of the Navy for research and development. Formerly, Dr. Wakelin was CIC's engineering vice-president.

Thomas J. Harriman has been elected as new vice-president of Giannini Controls Corp. In this position, he will continue his responsibility for integration of the company's activities in inertial and air-data control. Harriman came to Giannini in 1958 after 15 years with Bell Aircraft Corp.

David Y. Keim has been appointed chief engineer for military products of Stromberg-Carlson's Electronics Div. Keim previously served as engineering department head at Sperry Gyroscope Co. and also was employed by Sylvania Products Co.

Kimball C. Cummings will move from Minneapolis-Honeywell's Aeronautical Div. to be manager of engineering at the company's Beltsville, Md. Div. Cummings joined Honeywell's Research Div. in 1947 and was associate director of research at the aeronautical unit.

Obituary

Russell H. Varian, 61, inventor of the Klystron tube and chairman of the board of Varian Associates; of a heart attack while on a vacation trip to Alaska with his family.

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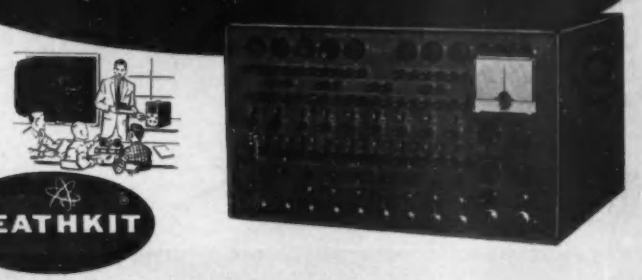

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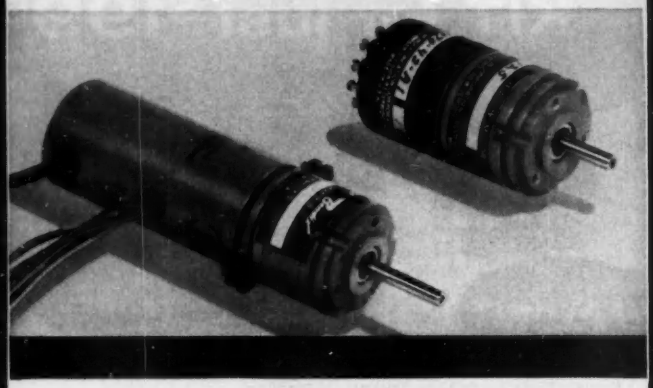

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BULLETINS AND CATALOGS

NOTE: This month's Bulletins & Catalogs section starts with several items for which written requests are necessary. Complete addresses are given for these items.

ROTOVALVE CATALOG. Allis-Chalmers Hydraulic Div., York, Pa. Scheduled to be ready for distribution after September 15th, a brand new 64-page catalog will be the most complete ever published on the A-C Rotovalve line. Sections will cover construction features, methods of operation, standard and special applications, and all the engineering data required to properly size and select valves. Special attention will be given to control problems which require valves with rangeabilities of 200 to 1 or greater or where high temperature, pressure, or vacuum is an important consideration.

PULP & PAPER CONTROLS. Conoflow Corp., 2100 Arch St., Philadelphia 3, Pa. Technical Bulletin MD-1 contains 16 pages of valuable data on the application of control valves, pulp stock valves, Saunders valves, pressure and liquid level transmitters, and other control equipment used in modern pulp and paper making processes. Flow diagrams illustrate such processes as sulfite acid preparation, brown stock washing, black liquor evaporation, stock proportioning, etc. Booklet also includes an explanation of the symbols used and a glossary of terms peculiar to the industry.

DYNAMIC INSTRUMENTATION. Endevco Corp., 161 East California Blvd., Pasadena, Calif. The first 24 pages of this 64-page brochure deal with specific products. Descriptions of accelerometers, pressure gages, force gages, amplifiers, and power supplies are accompanied by photographs and tables of complete electrical, environmental, and physical specifications. Balance of the booklet contains five technical papers presented at various symposiums. Titles of these include: "Performance of Three 500 Deg F Crystal Accelerometers", "Low Impedance Crystal Transducer Techniques", "The Measurement of In-Flight Vibration Under Environmental Extremes", and others on dynamic measuring techniques.

(350) VERTICAL GYRO. Grand Rapids Div., Lear, Inc. Bulletin GR-311, 4 pp. Summarizes performance and design characteristics of Lear's 1080 Series displacement gyro, designed specifically for severe vibration environments. Line drawing shows typical installation.

(351) FOIL STRAIN GAGES. Electronics & Instrumentation Div., Baldwin-Lima-Hamilton Corp., Bulletin 4320, 6 pp. Includes a two-page table covering specifications, prices, and new type designations for a complete line of SR-4 etched-foil strain gages.

(352) TURBINE FLOWMETERS. Cox Instruments Div., George L. Nankervis Co. Bulletin No. 1384, 4 pp. Introduces the Cox Type 20 turbine flowmeter, an instrument designed to provide an accuracy

within 0.5 percent of any reading over the entire range of the instrument.

(353) LIMIT SWITCHES. The National Acme Co. Bulletin EM-5912, 16 pp. Complete engineering drawings accompany descriptive literature on many of the Snap-Lock water- and oil-tight limit switches covered in this bulletin. Optional mountings and various operating levers are also described.

(354) ELECTRIC MOTORS. Redmond Company, Inc. Catalogs, 16 pp. Photos, dimension drawings, and performance tables illustrate the basic line of Redmond fractional-horsepower electric motors, blowers, and special products. Line includes shaded-pole, permanent split capacitor, and dc types.

(355) CR-TUBE DATA. Electronic Tube Corp. Chart. Lists the physical and electrical characteristics of over 60 single- and multi-gun cathode-ray tubes for industrial and military applications. Covers sizes from 2 to 12 inches, the new square and rectangular face types, and many special-purpose types.

(356) STABLE ELECTROMETER. Milton Roy Co. Engineering Data Sheet EIL 33/3, 4 pp. Presents a thorough discussion of the components, circuit arrangement, performance, and typical applications of the Vibron electrometer, an instrument developed for nuclear physics work and capable of measuring minute currents. Last page summarizes important specifications.

(357) RECORDERS & CONTROLLERS. General Electric Co. Bulletin GEA-6887, 12 pp. Describes a new family of continuous self-standardizing strip-chart recorders and recording controllers. Includes photos, application data, typical control system schematics, and brief notes on a variety of optional features.

(358) COMPUTER APPLICATIONS. Royal McBee Corp. Bulletin S-509. This is actually a reprint of a paper by Paul Seligmann, senior research physicist at the R&D Labs of the Portland Cement Association. Describes the problems that led to their acquisition of a small digital computer, an LGP-30, and the uses to which the Laboratory has put this machine.

(359) A-D RECORDER. Fischer & Porter Co. Catalog 35-1541, 8 pp. Reviews the design features and typical applications of a new recording device that converts an analog input, in the form of a shaft position, into a digital record, in the form of a binary-decimal coded punched tape and at the same time provides a coded output suitable for telemetering the digital information.

(360) REPORT ON SAGE. Burns & Roe, Inc. Spring, 1959 Report, 6 pp. Features a summary of the SAGE air defense system and describes some of the unique engineering problems encountered in the system's construction.

(361) AUTOPILOT SYSTEMS, Lear, Inc. Bulletin, 20 pp. Offers detailed information on a line of integrated flight equipment for transport aircraft. Includes graphic presentations of heading display, roll display, VOR/LOC courses interception, glideslope interception, and crab heading.

(362) MOTOR SHIELDS. Magnetic Shield Div., Perfection Mica Co. Data Sheet 146. Illustrates and describes how newly developed Co-Netic Netic magnetic shields enclose the field around shade-pole motors, eliminating detrimental magnetic interaction with other components in complete electronic packages.

(363) STRAIN-GAGE SUPPLIES. Neff Instrument Corp. Bulletin 201, 4 pp. Photos and a circuit diagram supplement descriptive data on the Neff 2-300 Series airborne strain-gage power supplies. Also included are plots of load regulation, temperature stability, and line regulation.

(364) FURNACE CONTROLS. Bailey Meter Co. Bulletin 514, 4 pp. Schematic and block diagrams illustrate the location and function of equipment used in a combustion control system for cyclone furnaces. Photos show the control panels at three typical installations.

(365) LVDT DEMODULATION. Schaevitz Engineering. LVDT Application Note 59-14, 8 pp. Describes a modified lvdt circuit designed to permit the use of an unbalanced load and to minimize nonlinearities in the dc output. Notes also illustrate direction-sensitive and multi-purpose types of demodulators.

(366) PRESSURE SWITCHES. Consolidated Controls Corp. Condensed Catalog, 4 pp. Covers a variety of airborne pressure switches. General purpose types include pneumatic, hydraulic, high-vibration, and differential pressure models. Also discusses some special purpose units such as altitude switches, pressure ratio switches, and high-temperature switches.

(367) CONTROLLED BLENDING. B-I-F Industries, Inc. Bulletin, 8 pp. One of a series on standard methods, this bulletin reviews the purpose, design, and operation of two types of two-component blenders: a flow responsive model and a controlled rate model. Photos and schematics illustrate both systems.

(368) CIRCUIT BREAKER LINE. Wood Electric Co. Catalog, 8 pp. Lists features and ratings for a variety of MIL spec circuit breakers and introduces a new series of commercial types which, while competitively priced, incorporate the heavy-duty features of the military types.

(369) WEIGHING SYSTEMS. A. H. Emery Co. Bulletin No. 591, 8 pp. Illustrates various types of 5,000-lb load cells and typical applications in packaged hydraulic weighing systems. Last page summarizes prices on cells, indicators, recorders, and other related equipment.

(370) GYRO DATA. Daystrom Pacific. Two brochures, 4 pp. each. Spell out the major design features of 1) floated free gyros and 2) rate gyros. Each brochure provides complete specifications and uses exploded views and airbrush drawings to illustrate gyro construction details.

(371) TIME/EVENT RECORDERS. American Electronics, Inc. Bulletin, 4 pp. Comprehensive presentation covers a full line of modular time and event recorders. Tables show the various combinations which can be produced from standard counters and time units.

(372) TAPE TRANSPORTS. Potter Instrument Co. Brochure, 12 pp. Describes Potter's complete line of digital magnetic and perforated tape handlers, record/playback heads, and amplifiers. Specifications listed cover virtually any digital application.

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(373) PRESSURE READOUT SYSTEM. Fischer & Porter Co. Catalog 30B1000, 12 pp. Contains a complete description of F&P's new multiple-pressure readout systems for rapid digital logging of as many as 250 different pressures. Shows how pressures are trapped simultaneously in comparators and scanned by a single transducer.

(374) NEW SYNCHRONOUS MOTOR. Superior Electric Co. Bulletin SS459, 12 pp. Full-color bulletin features photos, exploded view, circuit diagrams, dimension drawings, and performance curves on the new Slo-Syn line of permanent magnet type synchronous motors. One page shows how these motors can be adapted for use as dc incremental stepping motors.

(375) BREADBOARD PARTS. Helipot Div. of Beckman Instruments, Inc. Catalog 575, 24 pp. Gives the design engineer a complete description of all the parts necessary to assemble a variety of electromechanical servo systems. Components are presented in the order in which they would be used to set up a test system.

(376) INDICATING CONTROLLERS. Thermo Electric Co. Bulletin No. 65, 4 pp. Deals with a new line of electronic self-balancing indicators and indicating controllers designed to handle any process variable that can be converted to an electrical quantity.

(377) SEALED RELAYS. General Electric Co. Bulletin GEA-6628, 24 pp. This 1959-60 Sealed Relay Catalog updates earlier information on hermetically sealed microminiature, subminiature, miniature, and high-speed relays for military and general purpose applications. Provides circuit diagrams, photos, coil data, and complete specifications.

(378) POWER SUPPLIES. Neff Instrument Corp. Bulletin 201, 4 pp. Outlines operational characteristics and design features of a new line of airborne strain gage power supplies. Graphs illustrate load regulation, temperature stability, and line regulation.

(379) PROCESS COMPUTER CONTROL. ElectroData Div., Burroughs Corp. Brochure, 14 pp. Describes installations and applications of the Burroughs 205 electronic digital computer system in the petroleum and chemical industries. Applications cover exploration and production, manufacturing and refining, transportation and pipelines, as well as accounting and marketing.

(380) VARIABLE-SPEED DRIVES. Sterling Electric Motors, Inc. Bulletin No. 195, 4 pp. Features detailed information on the horsepower, duty, speed ranges, mounting styles, enclosures, and electrical characteristics of both standard and modified variable-speed drives for industrial applications.

(381) CONTROL VALVES. DeZurik Corp. Bulletin 150, 20 pp. Covers the operation and typical applications of the DeZurik control valves. Includes photographs, dimension and installation drawings, performance curves, and specification tables.

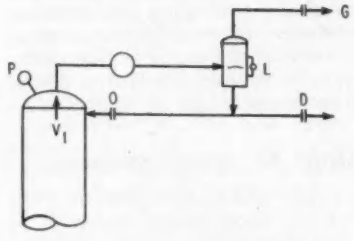
ABSTRACTS

Analog computing-control

From "Analog Computer-Control for Capacity Control of a Distillation Column" by W. O. Webber and R. L. Martin of Humble Oil and Refining Co., and J. F. Pink and J. T. Hargett of Southwestern Industrial Electronics Co. Paper presented to a session on instruments during the 24th Midyear Meeting of the American Petroleum Institute's Division of Refining in New York City, May 27, 1959.

The paper describes the control of a commercial distillation column by means of a computer whose cost was less than $10,000. The computer, produced by Southwestern Industrial Electronics, is a special-purpose analog type utilizing magnetic amplifiers, diodes, transistors, with no tubes or moving parts. The 50-plate fractionating column is part of a desulferization unit and charges a desulfurized light crude naphtha. The computer regulates the vapor rate in the tower to its maximum or capacity value by computing the vapor capacity of the tower, computing the actual vapor rate inside the tower, and controlling the reflux rate continuously to get this maximum.

The illustration shows the measurement points of the variables needed



to compute the percent-of-capacity according to the following relationships:

Calculate

$$V_{actual} = V_1 = (O+D+G+K_1 dL/dt)K_2$$

Calculate

$$V_{capacity} = V_2 = K_3(P+15)^{1/2}$$

Calculate per cent of capacity

$$= \text{per cent} = 100(V_1/V_2)$$

Where:

O = metered reflux, approx 40,000 bbl per day
D = metered distillate product, approx 13,000 bbl per day
L = level, ft
G = metered gas rate, approx 500 bbl per day equivalent
dL/dt = rate of change of level, ft per sec
K_1 = correction to bbl per day
K_2 = correction to bbl per day, inside

How UNION CARBIDE Verifies Flowmeter Accuracy

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Periodic checking of liquid flowmeters at the huge Oak Ridge, Tennessee nuclear facility presented a problem to the Union Carbide Nuclear Company, operators of the facility. Checking the instruments required a known standard against which they could be evaluated. Using other flowmeters as masters was of questionable value as they too were subject to the same variables of wear, temperature changes, and viscosity shifts as were the instruments under test.

Union Carbide solved the problem by using a *COX Flow Calibration Standard* (Type 315), the same as those used by flowmeter manufacturers for original instrument calibration. It gives them a *primary standard* of their own — assuring accurate flow measurements that can be correlated with measurements by the National Bureau of Standards.

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If you make or use flow measuring devices you will be interested in our new Technical Bulletin on *COX Flow Calibration Standards*. Write to: *Cox Instruments Division, George L. Nankervis Company, 15400 Fullerton Avenue, Detroit 27, Michigan.*

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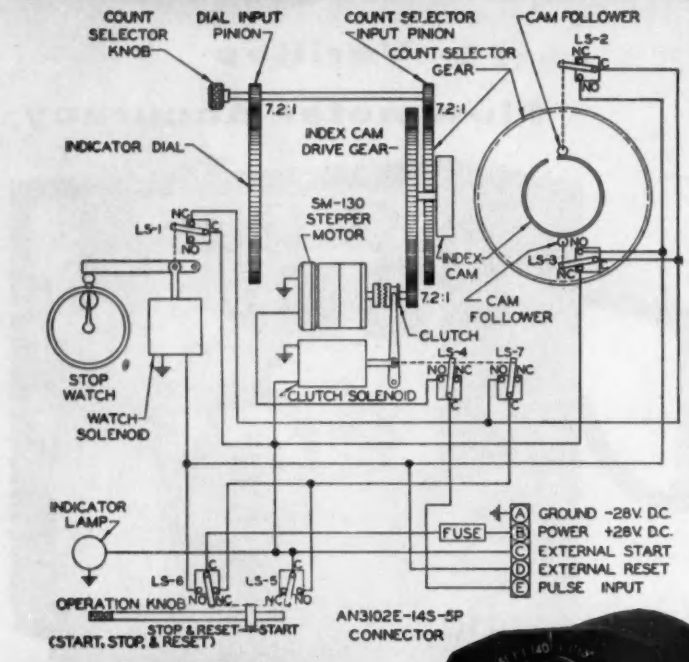

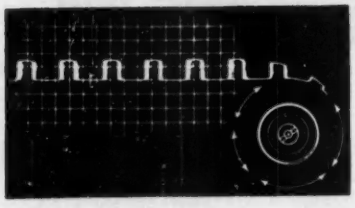

Model K-165

This Automatic Pulse Timer mounts in a standard 3⅛" mounting. The initial usage of the Automatic Pulse Timer was for a difficult instrumentation problem encountered on test aircraft—timing the pulses from a fuel flow transducer and thus determining specific fuel consumption. It successfully replaced a complex and unreliable method.

The Automatic Pulse Timer incorporates an uni-directional Stepper Motor along with complimentary gears, cams, solenoids, switches, an indicator light and—for an accurate independent time base—a stop watch. It is designed to visually record the lapsed time of an occurance of a specific number of electrical impulses. The Pulse Timer can count pre-selected quantity of 2 to 60 pulses, having a uniform or variable rate up to 25 pulses per second.

In this application the combined accuracy of the fuel flow transmitter and the automatic pulse timer is better than 1%, and of this the timer contributes essentially no error. When the broad input requirements are available, the unit can be used for timing pulses regardless of the source from which they may originate.

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ABSTRACTS

column to correct for enthalpy, 1.00 to 1.40
K_2 = entrainment constant
P = measured pressure, psig
15 = correction for absolute pressure.

Converted to analog computer language, the efficiency equation is:

$$\text{Efficiency} = \frac{K_2(C_O h_O^{1/2} + C_D h_D^{1/2} C_G H_G^{1/2} + K_1 dL/dt}{K_3(P+15)^{1/2}}$$

where the h's are 1-to-5 made input signals.

The reflux rate-of-flow controller is cascaded from the computer. This is essentially the same control scheme as that used without the computer, except that the reflux rate is adjusted by feeding the output signal from the computer to the index pen of the reflux controller. In other words, the percent of capacity is varied to achieve variation in reflux. The paper also discusses a practical but surmountable difficulty encountered during in-plant operation of the computer.

Calculating pressure drops

From "Durchflub und Verlusthohe in Absperrorgonen und Regelorganen", by Von G. Hutarew. Regelungstechnik, pp. 193-196, June 1959. (In German.)

The object of this contribution is to supply information for calculating the flow and pressure drop in pipe lines, on-off and modulating valves, etc., according to the latest developments in the science of dynamics. The calculations are supported by curves plotted from experimentally obtained data.

Stout on computer-control I

From "Computer Control of a Butane Isomerization Process" by T. M. Stout, The Thompson-Ramo-Wooldridge Products Co. Paper Presented at the Conference on Analog and Digital Instrumentation, AIEE, Philadelphia, April 20, 1959.

A vapor-phase process for converting normal butane to isobutane is used as a simple illustration of two techniques, systematic search and rules developed from a model by ordinary calculus, for process optimization by a computer-control system. The procedures are demonstrated using hypothetical relationships which represent, to some degree, a real process containing four reactors in parallel.

Optimization by search—The first procedure, a search technique, involves experiments on a mathematical model

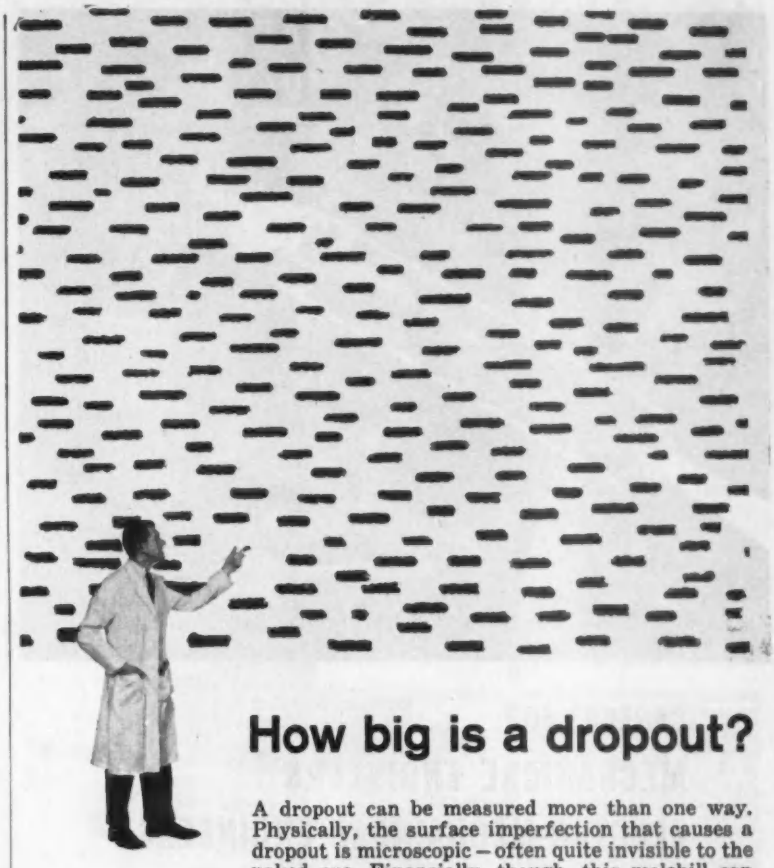
of the process by the control computer. It is based on the notion that the optimum operating point can be found by repeated application of rules which move the process from any acceptable operating point to a better one. The essential information at each step is the partial derivatives of the objective (maximum production rate) with respect to the manipulated variables; these figures can be obtained numerically for any sort of process objective and for models of any complexity.

[In the introductory part of his paper Dr. Stout distinguishes between optimization by a search procedure on a model and a search procedure on the process itself which, although carried out by a computer system, essentially duplicates the routine followed by an operator. This latter approach will be most successful when (1) a limited number of noninteracting variables are manipulated, (2) constraints are primarily upper and lower bounds on the manipulated variables themselves, and (3) the process responds in a time which is short compared to the intervals between external disturbances.]

After developing the characterizing equations of the process (the kernel of the computing-control problem) and establishing certain assumptions and constraints due to physical limitations, the author shows that the only variables entering the optimization calculations are reactor temperatures and feed rates. Thus, the computing-search procedure is to find the partial derivative of production rate with respect to temperature and the partial derivative of production rate with respect to feed rate, separately for each (of four) reactors. After solving for these derivatives, the new values of temperature and feed rates are computed, and the procedure is repeated until the optimum is calculated.

In computing the new temperatures, the computer uses the same idea as employed by an operator: if a positive change in temperature will cause a positive change in production rate, increase the temperature; but if a positive change in temperature will cause a negative change in production rate, decrease the temperature. Also, the change is made proportional to the expected benefit.

A slightly different procedure is used in determining the best feed rates. Here, the changes are made proportional to the difference between the individual partial derivatives and the average of the partial derivatives. By this device, the sum of the changes is zero and the total feed rate to all reactors is unaffected. From an operators's viewpoint, the control computer is taking feed material from the poorer



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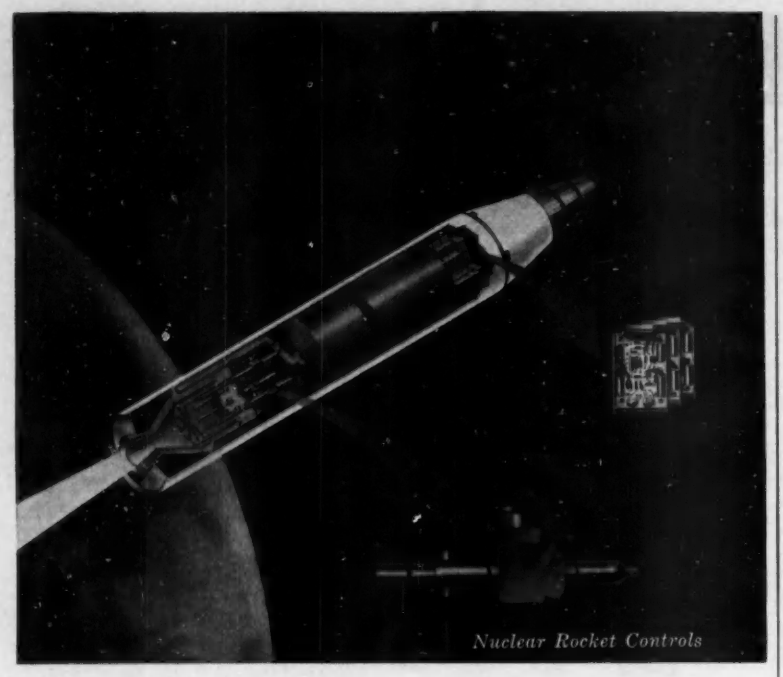
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ABSTRACTS

units and giving it to the stronger ones.

Study of this procedure reveals that it consists in changes in the variables in the direction of increasing production rate, alternating with calculations and corrections for violating of constraints. However, only the final result of an optimizing calculation is used to adjust process controllers; the temporary excursions outside the constraints exist only in the computer and cause no harmful effects in the process.

Optimization by calculus—It can be shown that, for this process, all temperatures and all partial derivatives of the objective with respect to the individual reactor feed rates must be equal to the optimum operating point and that for equal partial derivatives, if the temperatures are identical, the reaction severities must be equal, and conversely. Furthermore, either the temperature or reaction severity constraint will always limit process performance.

For this special case, then, the control computer need only compute

$$F_i = \left[\frac{K_{ei}}{\Sigma K_{ei}}\right] \Sigma F_i$$

where F_i = hydrocarbon feed rate to reactor i and K_{ei} = catalyst activity, related to reaction severity, in reactor i to obtain an optimum feed allocation between reactors. After this calculation, it can assume the temperature (or severity) is equal to the limiting value and check the severity (or temperature), reducing the temperature if necessary to meet a constraint.

Where applicable, this second approach to computing control discussed in Dr. Stout's paper leads to simpler computer programs requiring less memory space and computing time. In more complicated processes, however, using more realistic objectives and manipulating more variables, it may be very difficult to develop optimizing rules by analytical methods. If so, the systematic search procedure can still be used.

Compensating dead time

From "Uber die Beseitigung des Einflusses von Totzeit auf die dynamischen Eigenschaften von nichtlinearen Impulsregelsystemen", by Von S. Zypkin. Regelungstechnik, pp. 196-198, June 1959. (In German.)

Dead time may have a strongly unfavorable influence on the dynamic

properties of impulse-regulated control systems. This contribution describes two methods which enable this influence to be reduced by compensation so that, compared to the same system without dead time, the corrective action is but delayed by a constant time.

SOP for instrument installation

From "Refinery Instrumentation—a New Installation Guide by The American Petroleum Institute", by R. R. Proctor, The Pure Oil Co. Paper presented to a session on instruments during the 24th Midyear Meeting of the American Petroleum Institute's Division of Refining, NYC, May 27, 1959.

This paper announces the forthcoming publication by the American Petroleum Institute of a manual of recommended practices for the installation of instruments in petroleum refineries—the work of the Subcommittee on Instruments of the API Committee on Refinery Equipment. The paper gives a brief history of the development of the manual and a resume of its contents. The manual is intended to serve as a guide for the installation of the generally used measuring and controlling instruments and related accessories in order to achieve safe, continuous, accurate, and efficient operation with minimum maintenance. The purpose of the paper is to call refiners' attention to the manual which will be published sometime during late 1959 or early 1960.

Stout on computer-control II

From "Application of Computer Control in Pulp and Paper Manufacture" by T. M. Stout, The Thompson-Ramo-Wooldridge Products Co. Conference Paper 59-1017 presented at the AIEE Summer General Meeting, Seattle, June 22-26, 1959.

Where a technical basis can be found for using a control computer, it is also essential that dollar benefits be available which will justify the proposed installation. The cost of a computer control system might be as follows:

Computer	$100,000
Input-output equipment	40,000
New instruments	40,000
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Engineering	50,000
Total	$280,000

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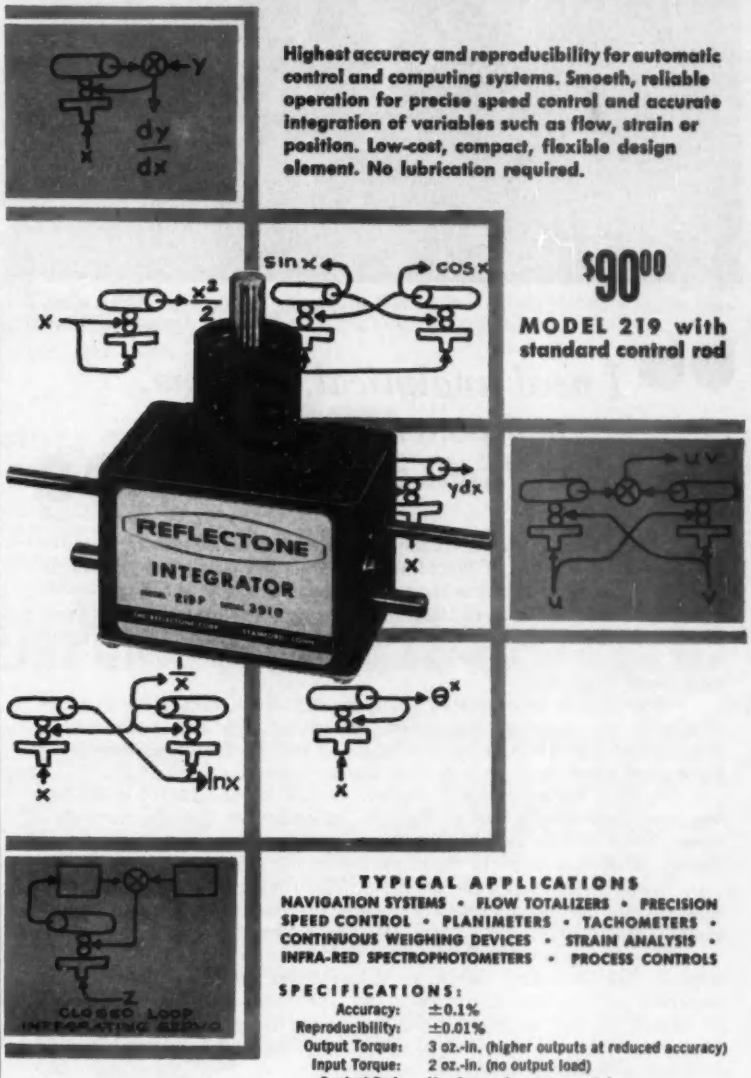

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measured and controlled variables; the cost of new instruments varies with the amount of instrumentation already in use; and the cost of process modifications (relocation of equipment, new facilities, enlargement of control room, etc.) can vary widely. Despite the uncertainties in the individual items, the estimate of total costs is representative of several actual systems. Its size suggests that careful thought will be given to the advisability of proceeding with an installation of a computer control system.

To show justification, Dr. Stout in his paper then estimates a rough but realistic idea of costs of wood, pulping, bleaching, fillers, sizing and coloring, and paper-making phases in a Kraft pulp and paper mill. The total costs of such important variables comes to slightly less than five million dollars annually for a mill producing 300 tons per day. A 3-percent reduction in these costs would save about $150,000 per year, enough to recover the estimated investment of $280,000 in two years. Without a detailed cost investigation, however, these figures are meant to suggest only that fairly modest reductions in manufacturing costs attributable to the computer control system could be sufficient to justify its installation.

Controller settings from noise

From "Der Einflub von Ableitungen der Regelgrobe auf den Regelkreis mit statistischer Storung", by Von M. Mesarovic. Regelungetechnik, pp. 198-203, June 1959. (In German.)

The adjustment of a controller will be satisfactory only if it is carried out according to the actual disturbances as they occur in practice. Random disturbances must be defined by their statistical properties described in terms of the spectral density. In this article the author has made use of the spectral density to calculate the optimum controller setting for disturbance pattern frequently occurring in practice by the method of minimizing the mean square error. The conclusion drawn is that disturbances of a statistical nature require slower controllers than do step disturbances. Generally it can be said that the broader the disturbance pattern becomes, the slower must the controller operate and the less marked will be the effects of the higher derivatives of the controlled variable.

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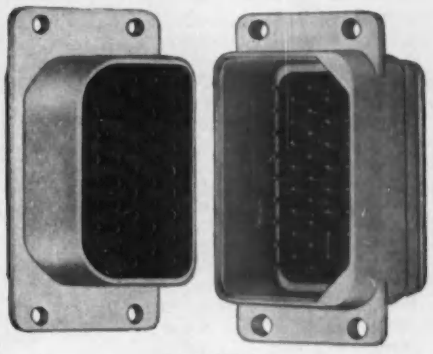

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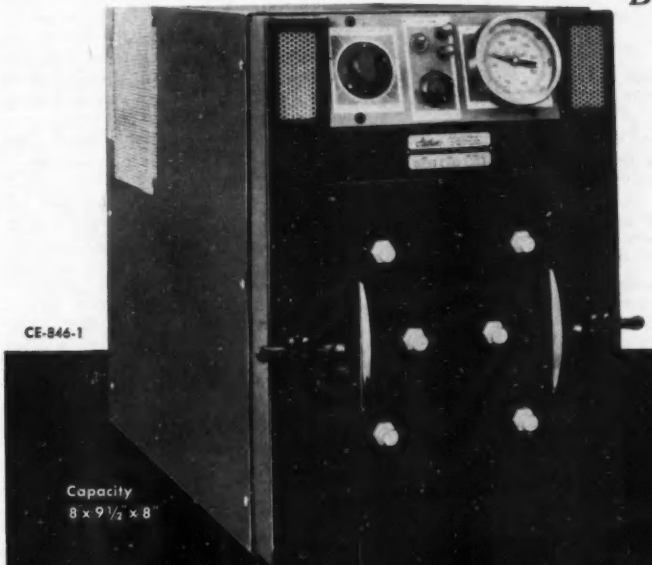

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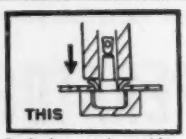

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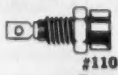

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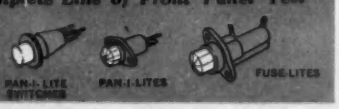

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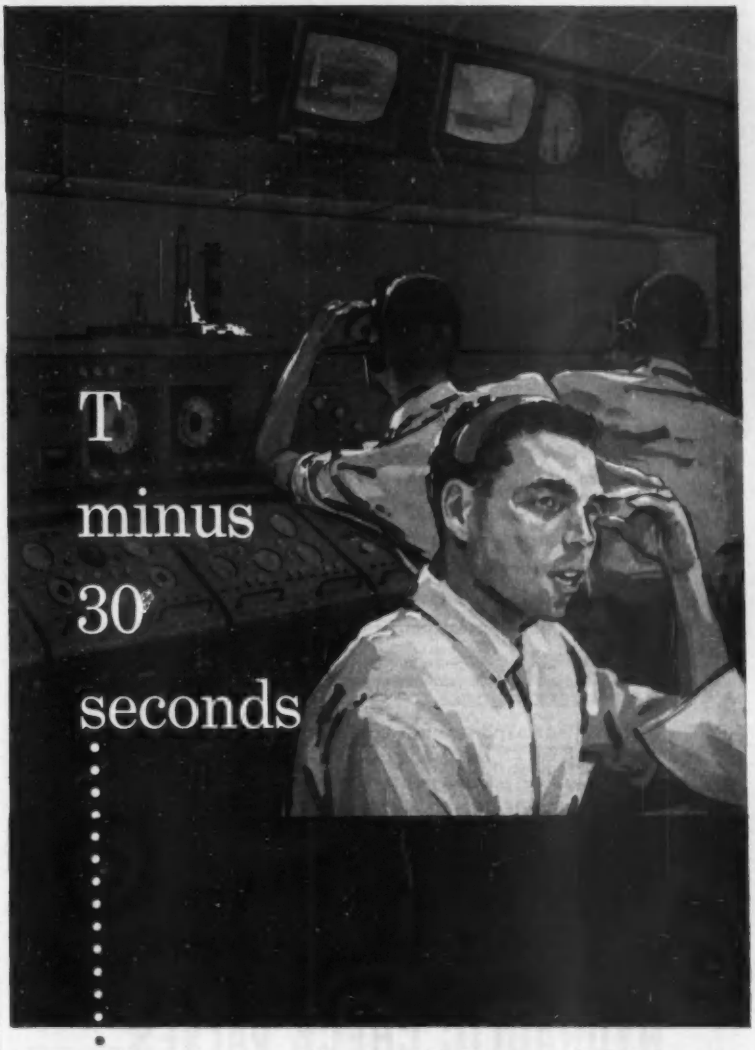

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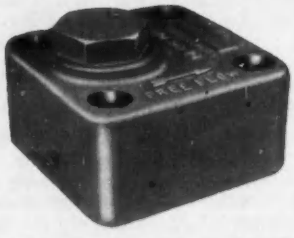

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Analysis Instrumentation — II — Refractometers, Infrared Analyzers, Photometric Analyzers, Colorimetry, 32 pp. This includes the second group of four articles of the Analysis Series. 60 cents.

Analysis Instrumentation — I — Nuclear Magnetic Resonance, Chromatography, Radioactivity, 32 pp. Reprint consists of first 4 articles of Analysis Instrumentation Series: a general introduction and detailed discussions of the three analysis techniques. Emphasis is on basic principles, practical tips, and the use of these techniques in automatic process control. 60 cents.

Basic Data on Process Control, 24 pp. A grouping of five articles on flow-process control, including: Basic Concepts of Feedback Control, Selecting Loops for Critical Control, Direct or Reverse Controller Actions, Modifying Valve Characteristics to Fit the Process, and Using Capacitance for Accurate Level Measurement. Practical information for every process control engineer. 50 cents.

How to Simulate Dead Time, 6 pp. Three tricky techniques for simulating dead time or transport lag. One's electronic, another is pneumatic-mechanical, and the third uses magnetic tape. A useful reference for control engineers concerned with process simulation. 15 cents.

Transistor and Thyratron Power Amplifiers, 28 pp. These three articles—one on transistors and two on thyratrons—were prompted by the increasing control application of transistors as low-power amplifiers and thyratrons as high-power amplifiers. In each case the emphasis is on

practical application, circuit design, system stabilization, etc. 50 cents.

Static Switching Devices—New Tools for Industrial Control, May 1957, 28 pp. An independent consultant analyzes the complete field of industrial static-switching systems. Starting off with a review of basic switching logic, he covers circuit characteristics of the fundamental devices, commercially-available systems, actual applications, etc. 50 cents.

A Functional Analysis of Automatic Logging Systems, February 1956, 16 pp. An examination of the various techniques and equipment used in performing the eight functions in a generalized automatic logging system: transducing, scale-factor correction and linearizing, derivation of quantities, scanning, analog-to-digital conversion, programming and control, alarm, and recording or logging. 50 cents.

Automatic Machining—A View and a Preview, 24 pp. A quick look at some of the newer techniques that are being used to control machine tools. It deals primarily with recorded-information (numerical) control, discussing ways to automatically furnish machining instructions, ways to drive the tool, or workpiece, and ways to measure position and size. 50 cents.

A System Analysis Predicts Performance, June 1955, 16 pp. This rare case history shows how determining the dynamic characteristics of both the process and the control system (and considering both open to modification) can reduce cost and improve performance. 50 cents.

The Use of Digital Computers in Science, in Business, and in Control, 112 pp. A collection of 14 articles published over a period of two years as the Digital Application Series. Prominent authorities cover the application, programming, overall system design, and commercial availability of digital computers in all phases of business, industry, and the military. $3.

• • •

CONTROL BITS

Cenco Instruments Corp., big producer and distributor of scientific laboratory equipment has acquired Soiltest, Inc., a Chicago firm that manufactures instruments to test the condition and quality of soil, concrete and asphalt. Soiltest, under its present management will be operated as a subsidiary of Cenco, says Alfred A. Strelsin, Cenco President.

•

Electronic Communications, Inc. has agreed to acquire Advanced Technology Corp., a small research and development firm in Santa Barbara, Calif., in exchange for 1,000 shares of ECI stock. ATC will be operated in Santa Barbara as a separate wholly owned subsidiary, with Stanley Jewell continuing as president and general manager. The scientific staff will be headed by Dr. Fritz K. Feldmann, formerly with the Avco Corp.

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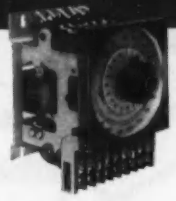

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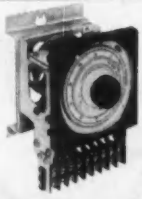

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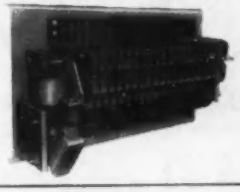

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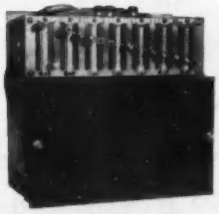

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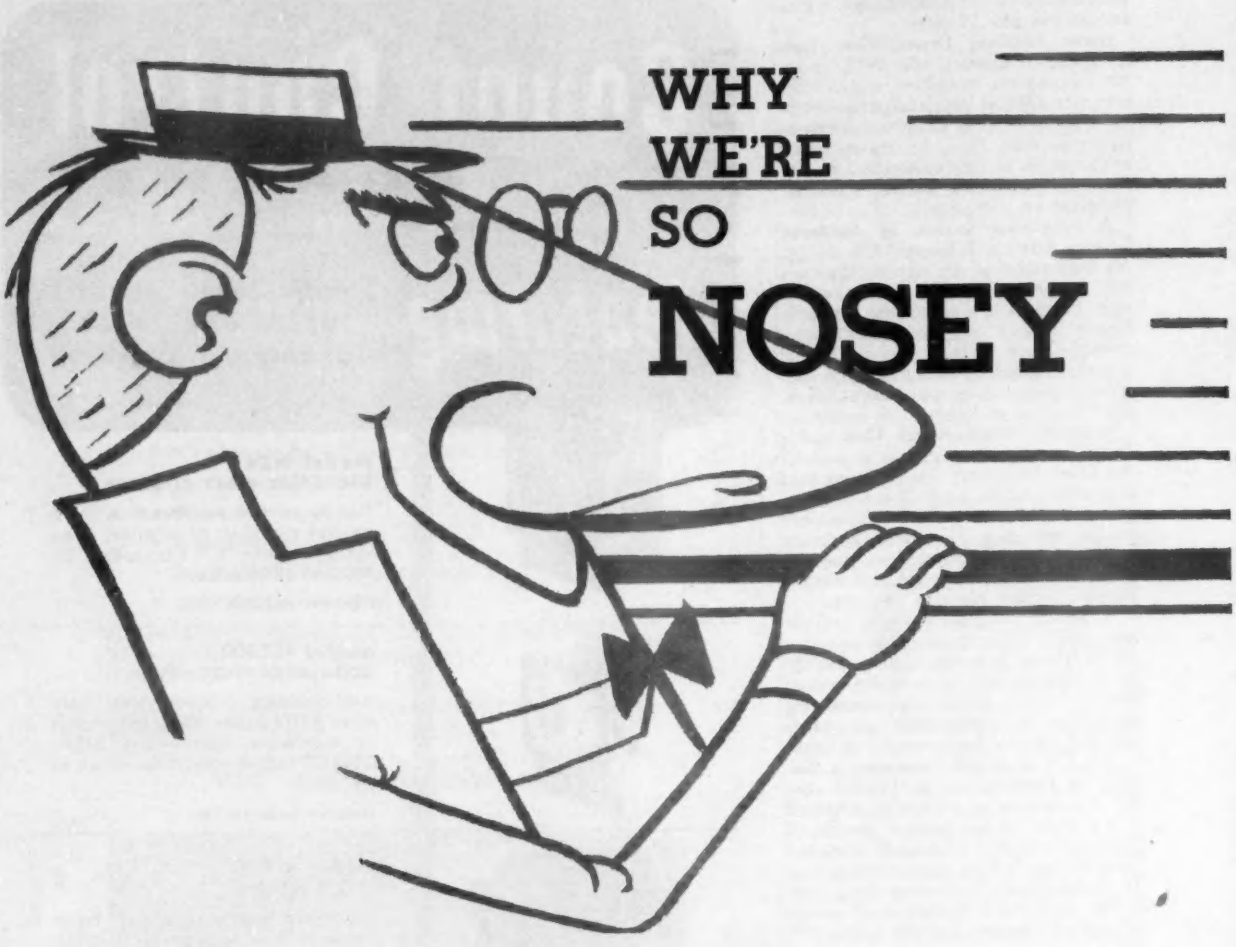

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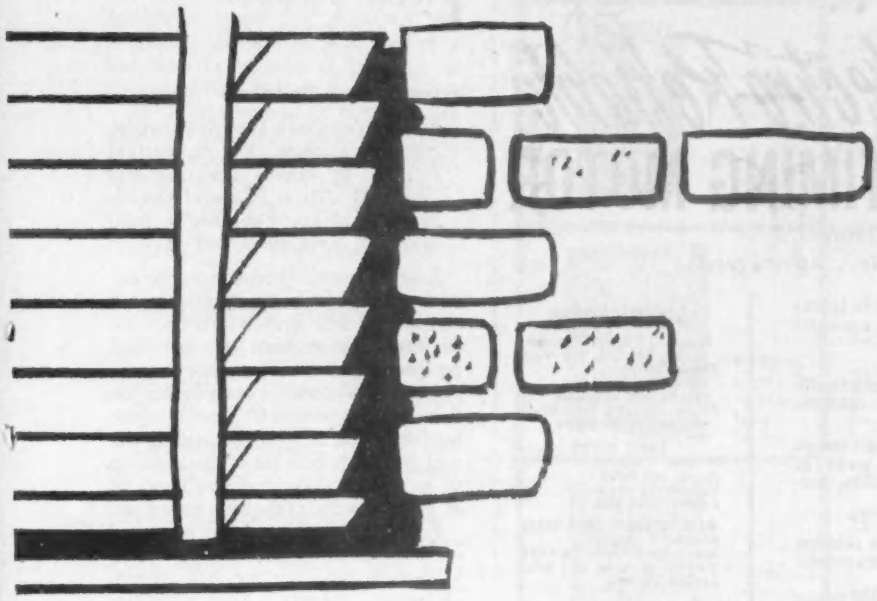

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SERVOMECHANICS AND REGULATING SYSTEM DESIGN, *Vol I, Second Edition, by Harold Chestnut and Robert W. Mayer (General Electric Series), 680 pp. Published by John Wiley & Sons, Inc., N. Y. $11.75.*

Like its famous predecessor, the second edition of Chestnut and Mayer's classic text was written primarily for engineers and students who have had no previous control engineering experience. It does an even better job than the first edition in presenting the fundamentals of control system design, primarily because of the addition of several new topics that should be in every control engineer's repertoire.

First, the authors have presented in this edition a discussion of root-locus plots and their use in determining system stability. They have also added a new chapter devoted exclusively to the application of root-locus to control system design problems. Included in this chapter are a numerical method for obtaining root-locus plots (Donahue's method), a detailed discussion of system compensation using the plots, and charts showing typical root-loci for systems with one, two, three, and four poles.

Second, the authors have supplemented their well-known steady-state and transient performance comparison charts by providing techniques for estimating closed-loop poles from the open-loop Bode plot. These techniques, based on work by Biernson and Chen, enable the designer to approximate the closed-loop transfer function and hence quickly estimate both transient and frequency response.

Third, this edition contains a chapter on the use of analog computers (by W. E. Sollecito). This is probably the first book on control system design that specifically emphasizes (and rightly so) that analog computers are tools of the control engineer, on a par with Nyquist and Bode diagrams and root-locus plots. This chapter by itself constitutes an excellent introduction to the theory and use of analog computers. The authors are to be commended for including it.

Other revisions of interest are: the use of ASA-recommended symbols and nomenclature throughout the book, an increase in the number of problems and examples, and a new treatment of control system error coefficients and their relation to system gain constants. Incidentally, this latter discussion contains the only seri-

ous typographical error in the book. The omission of a line of text at the bottom of page 240 destroyed the continuity of the authors' introductory remarks on error coefficients; an erratum should be issued.

All in all, the book is excellent. Its simplicity and clarity make it not only recommended reading for beginning control engineers, but also a good review for those practicing in the field.

Leslie R. Axelrod
The Powers Regulator Company

Tube Handbook Updated

POWER AND GAS TUBES, 32 *pp. Published by Commercial Engineering, RCA Electron Tube Division, Harrison, N. J.* $0.30.

This is a completely revised and expanded edition of the "RCA Power and Gas Tubes" booklet. It contains concise technical information on more than 175 RCA power tubes, rectifier tubes, thyratrons, and ignitrons. The revised edition presents data for a number of new beam power tubes including several small, compact, radiator types utilizing ceramic-metal seals for vhf and uhf applications and a super-power shielded-grid beam triode having a useful continuous-wave power output of 500 kilowatts. In addition to a description of each tube, the booklet provides photographs of representative types, diagrams of tube base and envelope connections, and tabular data including maximum plate ratings and typical operating conditions.

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AMERICAN STANDARD REQUIREMENTS FOR INSTRUMENT PRECISION BALL BEARINGS. *B3.10-1959. Published by American Standards Association, 70 E. 45th St., New York 17, N. Y.* $1.

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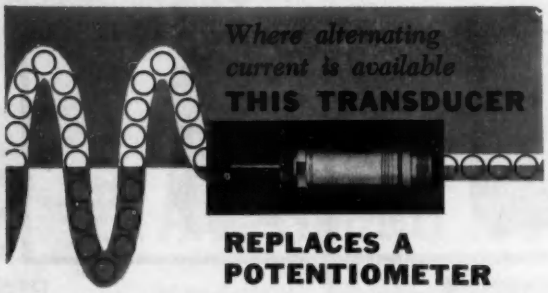

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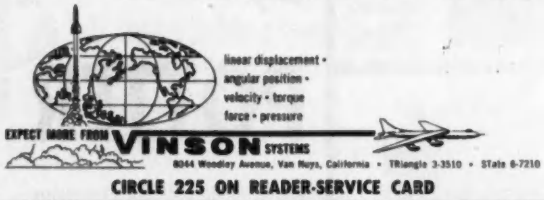
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MEETINGS

AUGUST

Annual Army Navy Instrumentation Program (ANIP) Symposium and Industry Briefing, Statler Hilton Hotel, Dallas, Tex. Aug 31-Sept. 2

SEPTEMBER

Association for Computing Machinery, 14th National Conference, Massachusetts Institute of Technology, Cambridge, Mass. Sept. 1-3

National Convention and Aerospace Panorama, sponsored by Air Force Association, Miami Beach, Fla. Sept. 3-6

American Automatic Control Council, General Assembly of IFAC, Edgewater Beach Hotel, Chicago, Ill. Sept. 14-18

Instrument Society of America, 14th Annual Instrument Automation Conference and Exhibit, International Amphitheater, Chicago, Ill. Sept. 21-25

Third Industrial Nuclear Technology Conference, sponsored by Armour Research Foundation and *Nucleonics* Magazine, Morrison Hotel, Chicago, Ill. Sept. 22-24

Fourth Annual Special Technical Conference on Non-Linear Magnetics and Magnetic Amplifiers, sponsored by IRE and AIEE, Shoreham Hotel, Washington, D. C. Sept. 23-25

American Institute of Chemical Engineers, National Meeting, Hotel St. Paul, St. Paul, Minn. Sept. 27-30

Institute of Radio Engineers, 1959 National Symposium on Telemetering, Civic Auditorium, San Francisco, Calif. Sept. 28-30

American Society of Mechanical Engineers, National Power Conference, Muehlebach Hotel, Kansas City, Mo. Sept. 28-Oct. 2

American Instiute of Electrical Engineers, Eighth Annual Industrial Electronics Symposium, Mellon Institute, Pittsburgh, Pa. Sept. 30-Oct. 1

OCTOBER

Institute of Radio Engineers, Fifth National Communications Symposium, Hotel Utica, Utica, N. Y. Oct. 5-7

National Electronics Conference, sponsored by AIEE, IRE, Illinois Inst. of Tech., Northwestern Univ., and Univ. of Illinois, Sherman

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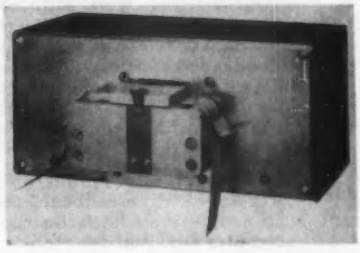

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MEETINGS

Hotel, Chicago, Ill. Oct. 12-14

American Standards Association, Tenth National Conference on Standards, Sheraton-Cadillac Hotel, Detroit, Mich. Oct. 20-22

Fifteenth National Conference on Industrial Hydraulics, sponsored by Illinois Institute of Technology and Armour Research Foundation, Hotel Sherman, Chicago, Ill. Oct. 22-23

Institute of Radio Engineers, East Coast Aeronautical and Navigational Electronics Conference, Baltimore, Md. Oct. 26-28

Society of Photographic Scientists and Engineers, 1959 National Conference, Edgewater Beach Hotel, Chicago, Ill. Oct. 26-30

American Institute of Chemical Engineers, N. Y. Section Meeting, Annual All-Day Symposium, Topic: Prospects for Computer-Controlled Processes, Hotel New Yorker, New York City. Oct. 27

Sixth Annual Computer Applications Symposium, sponsored by Armour Research Foundation, Morrison Hotel, Chicago, Ill. Oct. 28-29

Institute of Radio Engineers, 1959 Electron Devices Meeting, Shoreham Hotel, Washington, D. C. Oct. 29-30

NOVEMBER

11th Annual Mid-American Electronics Conference, Hotel Muehlebach, Kansas City Municipal Auditorium, Kansas City, Mo. Nov. 3-5

Institute of Radio Engineers, National Conference on Automatic Control, New Sheraton Hotel, Dallas, Tex. Nov. 4-6

Institute of Radio Engineers, Fourth Instrumentation Conference, Atlanta Biltmore Hotel, Atlanta, Ga. Nov. 9-11

Conference on Magnetism and Magnetic Materials, sponsored by IRE and AIEE, Sheraton-Cadillac Hotel, Detroit, Mich. Nov. 16-19

American Society of Mechanical Engineers, Annual Meeting, Chalfonte Haddon Hall, Atlantic City, N. J. Nov. 29-Dec. 4

Eastern Joint Computer Conference, sponsored by AIEE and IRE, Hotel Statler, Boston, Mass. Nov. 30-Dec. 3

27th Exposition of Chemical Industries, New York Coliseum, New York City Nov. 30-Dec. 4

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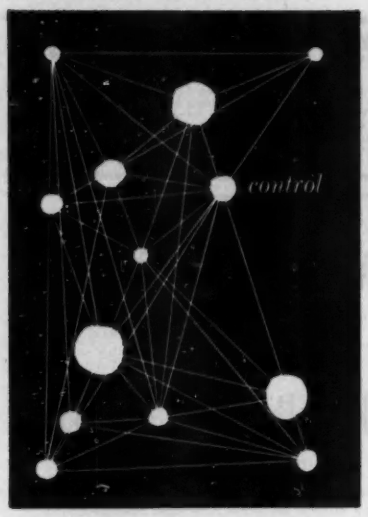

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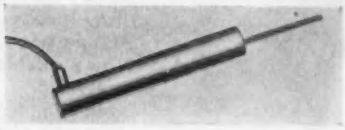

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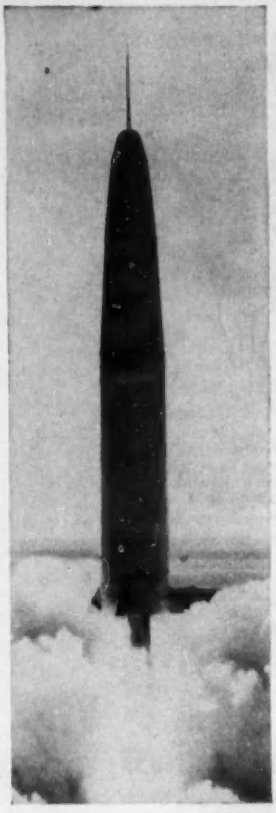

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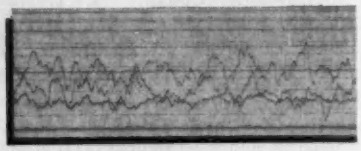

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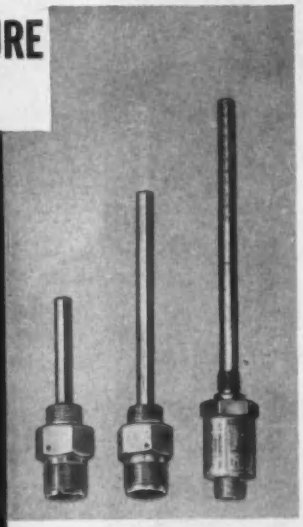

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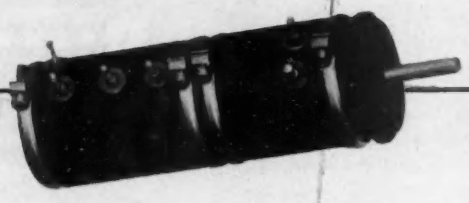

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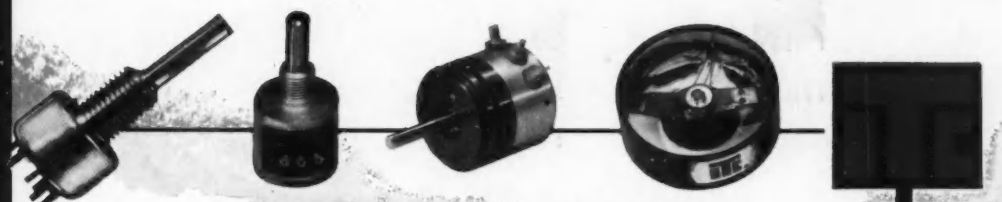


TECHNOLOGY INSTRUMENT CORPORATION

531 Main St., Acton, Mass., COlonial 3-7711

Executive Offices

Manufacturing, Research and Development Engineering

Box Type and Rotary Trimmers
Panel Controls TP Series
Servo type precision pots PVR Series
Non-linear special function
Prototype and Production runs
of non-standard single and
multiturn precision pots.

Rotary Metalfilm Potentiometers
Pressure Transducers
Displacement Transducers
Unitized Clutch Modules with
Commutator switches, brakes,
syncros, servo motors and
magnetic clutches.

ALTOMAC CORPORATION

863 Washington St., Canton, Mass.
Canton 6-1577
Subsidiary of **TIC**

Potentiometer Hardware
Fabrication

ALTOMAC

ACTON LABORATORIES, INC.

533 Main St., Acton, Mass., COlonial 3-7756

Subsidiary of **TIC**

Research, Design and Development, and Manufacturing of Electronic measurement and control instruments. Environmental Testing.

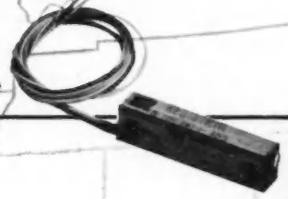
Phase Meters and Standards
Impedance Meters
Ponogometer Pot Test Equipment
Vacuum Tube Voltmeters
Oscillographic Recorders
Amplifiers
Precision Drives
Transistor Clips
Knobs and Dials

●

Environmental Testing

Life Test
Radio Frequency Interference
Vibration and Shock
Humidity, Mildew, Fungus, Salt
Fog and Spray, Rain, Sunshine,
Sand and Dust
Temperature, Altitude and Explosion

Servo-trol



SERVOTOL, INCORPORATED

10130 West Pacific Avenue, Franklin Park, Ill.

Gladstone 1-1140

Subsidiary of **TIC**

Manufacturers

Box Type Miniature Trimmers, Metal and
Plastic Housings
High Temperature Resistant — Lead Screw
Adjustments For Fine Trimming
Wirewound and Metal Film Types

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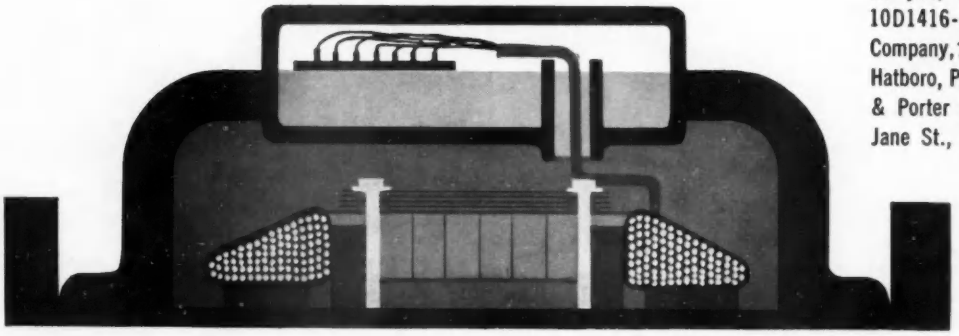
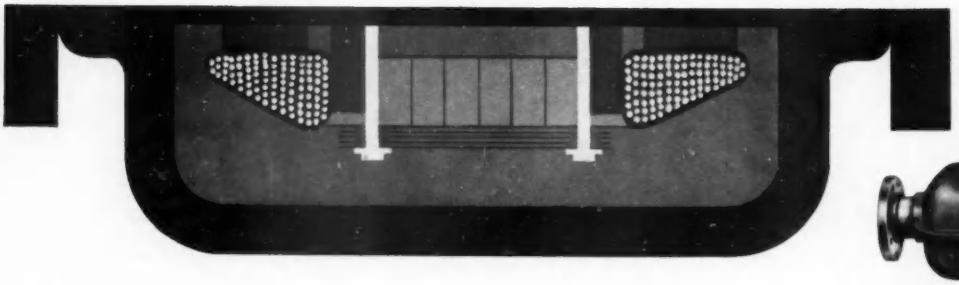


ACETALDEHYDE • ANHYDROUS AMMONIA • BENZYL ALCOHOL • DISTILLED WATER • FORMIC ACID

HYDROGEN CYANIDE • ISOPROPYL ALCOHOL • LIQUID PHOSPHORUS • O-TOLUIDINE • SULFONIC ACID • URIC ACID



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COMPLETE PROCESS INSTRUMENTATION

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